The AMSAT Journal

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Notes from the field ...

Phase 3D Spacecraft Integration Meeting held in Florida

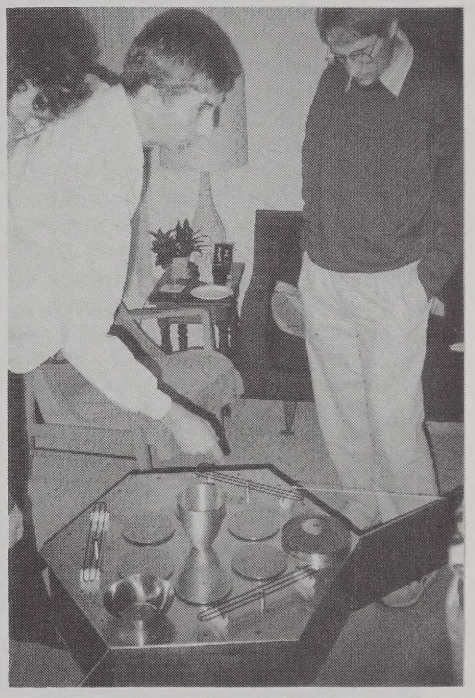
About a half dozen members of the North American Phase 3D Development team met recently to assess overall progress on the program and to begin planning for the spacecraft's final assembly in preparation for its April, 1996 launch from Korou, French Guyana.

Dick Jansson, WD4FAB, AMSAT VP for Engineering, hosted the North American Phase 3D progress meeting near Orlando, Florida on 7-9 January, 1994, where a number of critical Phase 3D issues were discussed. While several open items still must be resolved, AMSAT-NA's overall technical contributions to the Phase 3D project remain on track.

The high point of the meeting came when several officers of a Florida-based volunteer group, called Space Frontier Operations (SFO), presented their proposal to manage the overall integration effort for the Phase 3D spacecraft. After extensive discussions concerning their capabilities and proposed integration approach, SFO's offer was gratefully accepted.

Also on hand for the meeting were Keith Baker, KB1SF, AMSAT VP, Strategic Planning, who discussed the overall Phase 3D Master Schedule. In addition, Stan Wood, WA4NFY, updated the team on Phase 3D's

Continued on page 23



AMSAT's Stan Wood, WA4NFY, explains the details of his latest Phase 3D model to Jan King, W3GEY (R) and SFO's Mike Peacock, KR4GA (L). *(KB1SF Photo)*

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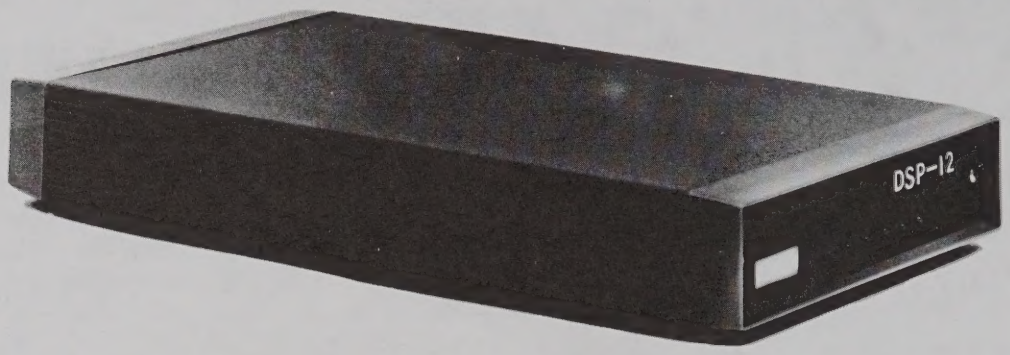

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New Blood

by Bill Tynan W3XO

One of the objectives common to almost all volunteer-based organizations is the need for new people to carry on the work of the organization. AMSAT is no exception. In fact, one of our continuing problems has been the relatively small number of talented people willing to furnish their skills, without compensation, to amateur satellite programs. With the commitments AMSAT-NA has made to Phase 3D, this situation has been quite serious. I say "has been" because a group of trained, talented space professionals has been located which has great potential for contributing significantly to the Phase 3D project.

As a direct result of pleas for help by Dick Jansson, WD4FAB, AMSAT's Vice President for Engineering and principal mechanical and thermal designer on Phase 3D, a group called Space Frontier Operations, or SFO, has stepped forward and is volunteering to fill a critical void in the process of completing the satellite. AMSAT-NA had previously volunteered to undertake the vital task of integrating the spacecraft. Integration, quite simply means "building and testing". Parts will come from many places. The structure will come from Utah where students at Weber State University are now busy machining pieces. An AMSAT-NA group of volunteers are providing a GPS system for orbit determination and accurate time. Propulsion components will be arriving from various sources, including Germany, Russia and the U.S. Various transmitters will be provided by groups in Germany, the U.K., Finland, Belgium, and South Africa. There are computers from Germany, solar panels and batteries from this country and a number of receiver modules from various countries including several from Slovenia. Integration involves putting all of these items together and making sure that the resulting satellite will work properly. It is far from a simple task.

I have just returned from a meeting held in Orlando, Florida to make specific plans for our near-term activities. In addition to several other key AMSAT people, a number of SFO members were also in attendance. All of those I met at this meeting impressed me greatly in terms of both their commitment and capability. Basically, they have agreed to take on the task of running the integration facility, including such diverse activities as training of all personnel that will be working in the facility and generating all of the extensive safety documentation which will be required before Phase 3D can be admitted to the French Guyana launch complex. Quite simply, integration is a very complex and demanding task which we were wondering how we could do with the few qualified people we had available. Many of the SFO folks have been accomplishing just such kinds of work professionally in their jobs at Cape Canaveral. In short, SFO appears to be a godsend to the Phase 3D project.

What is SFO and why are they interested in making such a major commitment to our amateur satellite program? Space Frontier Operations is a young organization, having been formed about two years ago. It is a nonprofit organization with a current membership of somewhat less than one hundred. However, what it may lack in numbers it appears to more than make up for in experience, competence and enthusiasm. My background in the engineering world has taught me to listen to see what questions a new person asks. The SFO people asked all the right questions. In addition, they made many solid suggestions for specific satellite design approaches - ones that should significantly facilitate the integration process.

You may wonder why SFO is interested in participating with us in the Phase 3D project. I wondered the same thing. Their answer was that they have plans for future participation in a variety of space ventures including a near-term plan for construction of a Get-Away-Special (GAS) can package for a Shuttle mission. They believe that major participation in the integration of Phase 3D will establish their credibility for other, future activities.

So, it appears that an excellent synergy exists between our aims and those of SFO and thus we can both do each other a significant amount of good.

We welcome SFO's participation in the Phase 3D project and trust that this association will be a most productive one for both AMSAT and SFO.

MANAGING OSCAR-13

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Abstract

The Oscar-13 satellite is 150 kg of spinning tri-lobed chassis. Outwardly it's covered with solar panels, inwardly it's filled with batteries, a control computer, navigation sensors and associated interface electronics. In addition there are four linear transponders used for long range SSB voice and CW amateur radio communications. The management objective is to ensure that the hardware is controlled in such a way as to ensure the most efficient use of these transponders. A member of the Phase 3 management team for nearly a decade, the author describes how it's done.

1. AO-13 AS A CONTROL SYSTEM

It is instructive to view the management of Oscar-13 in terms of a feedback control system, figure 1. Objectives, which are tempered by known disturbance factors, are used to formulate a control strategy. The strategy is implemented by means of commands transmitted to the satellite.

The spacecraft itself responds in a deterministic way to the commands and environmental disturbances, but in a random way to the much smaller unknown factors, mainly drag effects. This determinism is fortunate, since it means outline plans can be formulated several years in advance, and potential problems anticipated very early.

The satellite tells us about itself via the telemetry beacons, and the received data is then subject to interpretation. This analysis of the actual (as opposed to expected) spacecraft performance can then be compared with the original objectives, and the control cycle repeats.

In figure 1, factors on the right hand side are only accessible via radio links. The left hand side is represented by pieces of paper, telemetry decoders, computer analysis programs, telephone, fax, e-mail and of course command stations or managers.

From a practical point of view, having people as an integral part of the control mechanism introduces little degradation because the system dynamic is very slow indeed, measured in days rather than milliseconds. Thus it is sufficient to check out the telemetry no more than once a week or so - although for the author it is, by choice, a daily operation.

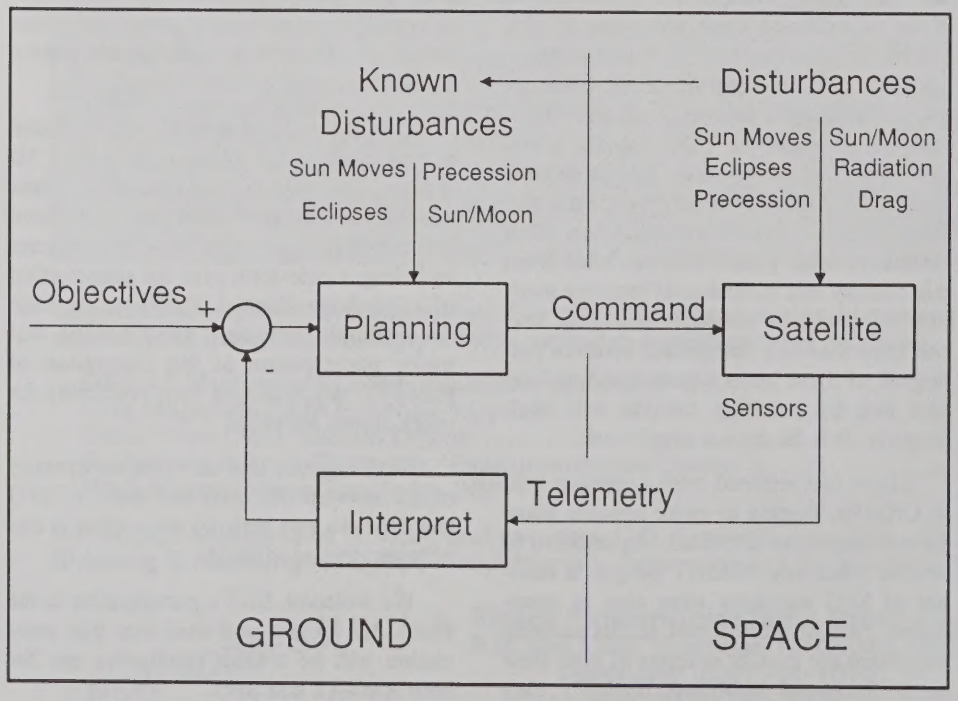

Figure 1. A satellite can be thought of as an element in a control loop.

So this review paper takes that model as a guide, and the various topics will be discussed in this context:

* Objectives
* Disturbances
* Control Strategy
* The Oscar-13 Satellite
* Telemetry
* Interpretation
* Telecommand

2. OBJECTIVES

The AO-13 control objectives are remarkably concise:

* Healthy battery charge
* Optimise orientation
* Optimise transponder availability
* Publish information

These factors are interlinked. The primary task is to keep the battery healthy, otherwise there could be no transponder usage. But this requires the satellite's orientation with respect to the Sun and users on Earth to be controlled in the best way.

This in turn dictates which transponders should be on during which part of the orbit, because some of the antennas have a more narrow beamwidth than others. With the demise of the 435 MHz transmitter in May 1993 this requirement was somewhat simplified because both remaining transponders, mode-B and mode-S can be operated simultaneously for long periods.

A healthy battery is one that a) retains a net positive power balance, and b) does not drop below the threshold of 12.6 volts at any time; fully charged is 14.5 volts.

The preferred satellite orientation is that which points the antennas at the Earth when the satellite is at maximum distance, or apogee. However this ideal can only be

achieved for 20 weeks of the year, and at other times up to 60° of off-pointing is required. This is no great disadvantage, since the satellite's range during the best part of these periods is still substantial, giving good Earth coverage.

3. DISTURBANCES

In the control sense, there are several factors which change the satellite's circumstances and require action if the objectives are to be realised.

Known Factors

* Sun's annual movement
* Eclipses of the Sun by Earth and Moon
* Orbital precession

Unpredictable

* Random torques
* Radiation effects
* Failures
* Battery and Panel Ageing

3.1 Known Factors

Oscar-13 is spin stabilised at typically 25 r.p.m. In principle it points towards the same spot in the heavens all the time, just like a gyroscope. Therefore from the satellite's point of view, the Sun is continuously moving around at a rate of 1°/day, and consequently sunlight strikes the solar panels at a slowly changing angle.

At best, the Sun is perpendicular to the spin axis, and gives maximum illumination. At other times it can be up to 45° off axis, resulting in Cos 45° = 0.71 or 71% illumination. This represents the safest minimum with the mode-B transponder ON for half an orbit.

When the Sun's position lies close to the satellite's orbit plane, Earth casts a shadow across the satellite's path. When the satellite then passes through this point it is cut off from sunlight, a condition known as eclipse and the battery receives no charge. Oscar-13 experiences eclipses for typically 20 minutes per orbit most of the year at perigee. For a few weeks eclipses occur at apogee, and can last nearly three hours. Short eclipses can easily be accommodated by the battery, long ones cannot, necessitating transponder closedown for part of the orbit.

Occasionally the Moon interposes between Sun and satellite, and this too needs to be anticipated. Periods can be a few minutes and a partial obscuration, to a total eclipse of several minutes and an overall encounter lasting an hour or more.

While the spin axis orientation is fixed in space, the orbit plane is not. It drifts very slightly. The plane rotates around Earth's equator at -0.17°/day, and the apogee/perigee line moves round the orbit plane at 0.07°/day (in 1993). So the spin axis direction, with which the antennas are coaxial, as seen from the orbit plane appears to drift slowly by a degree or two per week. This calls for occasional correction.

3.2 Unpredictable Factors

The forgoing known factors can all be explicitly accounted for in the management plan. There are however some less predictable effects. As the satellite swoops past Earth at perigee, even though the altitude is well over 500 km in 1993, it receives a slight buffeting. This shows up as a) a steady fall in spin rate (-0.06 r.p.m./day in 1993) which is consistent over time, and b) a random wander in spin axis direction by as much as 1°/month. This might seem to be a trivial matter, but the whole basis upon which measurement of the spin axis direction is founded is its property of gyroscopic invariance, so considerable judgement is needed when interpreting sensors' data.

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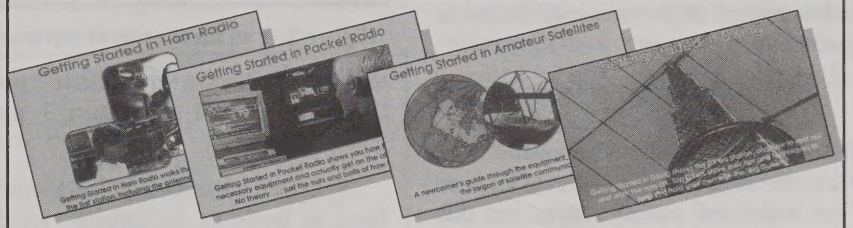

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There is also the effect of radiation. This is detectable as "hits" on the flight computer's memory, but this is Hamming-code protected, and so self correcting. Hits on the computer itself appear to have resulted in just two software crashes in the 5 years since launch. In the longer term solar panel output will degrade, and this is just becoming discernible. There is also evidence that the main battery pack has reduced storage capacity.

3.3 Failures

There have been (up to 1993) only two failures aboard Oscar-13. The RUDAK digital module refused to boot up properly immediately after launch, despite a year's exhaustive on-air testing from a water tower in Ismaning, Germany. For a short while it responded to short test programs, but soon that ceased also. No explanation has been found; a cracked PCB trace or IC failure is suspected.

The 435 MHz transmitter failed abruptly on 1993 May 19, thus eliminating mode-L and mode-J operation. Tests with large EME antennas and DSP techniques have so far not heard the exciter stages, but this work continues. [2]

4. CONTROL STRATEGY

Given the mission objectives and environmental influences, a strategy or plan has to be drawn up to realise these goals. This is by far the most time consuming job in AO-13 management. Factors to be considered are:

* Solar illumination vs attitude
* Attitude drift
* Squint plots
* Schedule planning
* Magnetorque simulation

To examine these factors the command stations use a suite of analysis programs evolved by the author since 1984.

4.1 Solar Illumination vs Attitude

The most important influence on Oscar-13 is the Sun angle. This is the angle the Sun makes with the satellite's spin equator. See figure 2. Maximum illumination is received when this angle is zero, while if it were 90° Sun and spin axis would be coaxial, and there would be no illumination at all.

The spin axis direction has to be controlled so as to maintain a favourable Sun angle at all times. To investigate the value of Sun angle as a function of spin axis direction, also known as "attitude", program ILLPLAN is used, and figure 3 shows a typical screenshot.

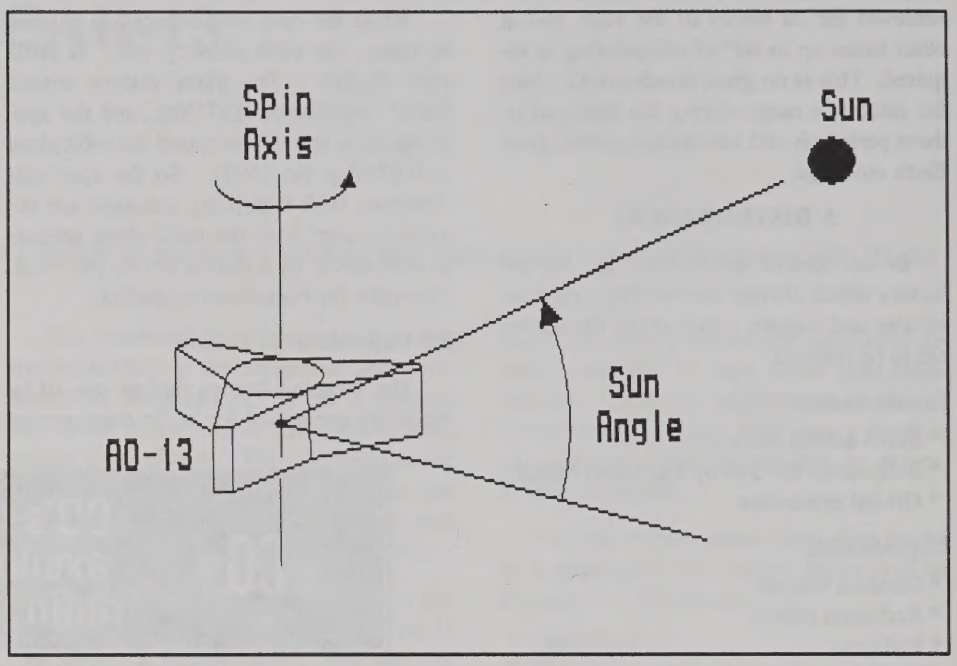


Figure 2. The most critical environmental factor is Sun Angle, defined as illustrated.

Spin axis direction is conventionally defined in terms of an attitude "longitude" around the orbit plane, starting at perigee direction = 0°, apogee direction = 180° and so on, whilst direction out of the plane is called attitude "latitude". Figure 3 tabulates latitude at the left hand side, and longitude across the page, so the presentation is map-like.

For any combination of attitude longitude/latitude a number is displayed, which is the Sun angle that will be experienced. If that number exceeds ±45° a +++ or — is displayed instead; this indicates a no-go zone due to low illumination. If outside ±60° a blank is shown. At those attitudes the on-board navigation sensors will fail as they cannot see the Sun. The blank area is of course the direction of the Sun; its longitude Saz and latitude Sel is printed at the top.

By pressing the < or > keys this table can be instantly indexed backwards or forwards by 7 days, and so provides a dynamic cartoon film of Sun angle vs attitude prospects. The nominal Earth-pointing-at-apogee condition is longitude 180°, latitude 0°, i.e. the middle of the chart. In the example illustrated this would result in a +++ or no-go condition. So the satellite would have to be oriented either to the left or the right of centre, for example at longitude 210° or longitude 120°. The choice is made from considerations of squint angles for northern and southern hemisphere users (see section 4.3), and favours 210°. In this example the no-go zone moves vertically up the diagram some 1° per day, and allows a nominal 180°/0° spin axis direction to be restored on July 11th.

By liberally exercising this program a sequence of orientations can be chosen as much as two years in advance which will guarantee favourable attitude and Sun angle combinations.

1994 Apr 18 [Mon] SEL= -33.8 SAZ= 158.9 WP= 338.2 RAAN= 257.5 IN= 58.0

LA\LO	260	250	240	230	220	210	200	190	180	170	160	150	140	130	120	110	100	90
15	-17	-9	-1	7	14	21	27	33	37	40	41	41	38	34	29	23	16	8
10	-15	-6	2	10	17	25	31	37	42	45	+++	45	43	38	33	26	19	11
5	-12	-4	5	13	21	28	35	41	+++	+++	+++	+++	+++	43	37	30	22	14
0	-9	-1	7	16	24	31	39	45	+++	+++	+++	+++	+++	+++	40	33	25	17
-5	-6	2	10	18	27	35	42	+++	+++	+++			+++	+++	44	36	28	20
-10	-4	5	13	21	29	38	+++	+++	+++					+++	+++	39	31	23
-15	-1	7	16	24	32	40	+++	+++						+++	+++	42	34	26

Figure 3. The spin axis direction has to be controlled so as to maintain a favourable Sun angle at all times. To investigate the value of Sun angle as a function of spin axis direction, also known as "attitude", program ILLPLAN is used.

4.2 Attitude Drift

A program used in conjunction with the forgoing is called ATTHIST. Once an orientation of the satellite has been achieved it is left untouched for as long as possible. Reorientations are time consuming, and confusing for users. A typical analysis is shown in figure 4.

Given an initial orientation this gives a week by week breakdown of key data, in this case the familiar Earth-pointing-from-apogee condition longitude 180° latitude 0°. The Sun angle is of greatest importance, and is seen to start at +36°, fall through zero, reaching the nominal limit of -35° in late September, dictating a re-orientation.

Other parameters of interest are the percentage solar illumination (100 Cos SA), the Sun's position in longitude (Saz) and latitude (Sel), and the familiar keplerian elements argument of perigee and RAAN. An understanding of the Sun's position is essential in management as it influences the ease or difficulty of attitude measurement via the on-board sensors, though it is of no importance from the user perspective.

4.3 Squint Plots

Once an attitude schedule has been fixed, driven only by Sun position constraints, the next task is to devise a transponder mode-schedule. [14]

By far the most important quantity in Oscar-13 communications is known variously as the pointing or squint angle. This is the angle between the spacecraft's antennas and the user. See figure 5. If this angle is large, communications are poor quite regardless of anything else. So a study of squint angle forms the next stage of the planning process.

Some of the spacecraft antennas have a narrow beamwidth, notably the 1269 MHz receive which is a 5 turn helix, and the 2400 MHz transmit, a 4 turn helix. Their -3dB beamwidths are of the order of ±20°, so there is little point in seriously exercising them when signals arrive or depart at angles worse than this.

On the other hand, there are also omnidirectional whips for 145 and 435 MHz, and these must be used sideways on and at short range.

With this in mind program SQPLOT is used to determine the pointing angles as a function of time through each orbit for a representative 10 day period. This can be done for a typical user at 45°N or 35°S, and for any specified satellite orientation.

A typical plot is shown in figure 6. Squint is the vertical axis, while the horizontal is mean anomaly in 1/256th orbit period. Superimposed on the plot are candidate periods for mode-L and mode-S operation. (Since the demise of mode-L, that time is now allocated to mode-S).

In this way a mode switching schedule can be devised, and is eventually published in the familiar format, figure 5a.

4.4 Magnetorque Simulation

Re-orientation of the satellite from one spin direction to another is achieved by an on-board system called a magnetorquer. Wound around each of the three spacecraft arms is a large solenoid. These three coils form the rotor of an electric motor; the "stator" is the Earth's magnetic field. Commutation is provided by the on-board computer which switches current through the coils sequentially in synchronism with the spin.

When the Earth's magnetic field lies on the satellite's spin equator we have a pure motor, in that spin rate can be increased or decreased or simply maintained. If it lies off-equator then the resulting non-coaxial torque allows the spin direction to be changed as well.

Magnetorquing is strongest when the Earth's magnetic field is strongest, and so only takes place at perigee encounter, essentially within MA = ±10. During fly-by the field also changes greatly in direction, and this ensures a rich profile of torques can be generated. Typically a movement of 5° can be achieved per perigee pass. However during eclipses, the spacecraft is deprived of its reference direction the Sun, so magnetorquing is impossible at that time.

DATE	ALON	ALAT	SA	ILL %	SEL	SAZ	Arg P	RAAN
1994 Jul 11 [Mon]	180.0	0.0	36.4	80.5	50.9	199.9	343.8	242.9
1994 Jul 18 [Mon]	180.2	1.0	29.8	86.8	57.4	206.7	344.3	241.7
1994 Jul 25 [Mon]	180.3	2.0	23.1	92.0	63.4	216.3	344.7	240.4
1994 Aug 1 [Mon]	180.5	3.0	16.5	95.9	68.5	230.6	345.2	239.2
1994 Aug 8 [Mon]	180.7	4.0	9.8	98.5	71.7	251.2	345.6	238.0
1994 Aug 15 [Mon]	180.8	5.0	3.1	99.9	72.0	276.1	346.1	236.8
1994 Aug 22 [Mon]	181.0	6.0	-3.6	99.8	69.3	298.1	346.6	235.6
1994 Aug 29 [Mon]	181.2	7.0	-10.3	98.4	64.5	313.7	347.0	234.4
1994 Sep 5 [Mon]	181.3	8.0	-17.0	95.6	58.5	324.1	347.5	233.1
1994 Sep 12 [Mon]	181.5	9.0	-23.8	91.5	51.9	331.3	348.0	231.9
1994 Sep 19 [Mon]	181.6	10.0	-30.6	86.1	44.9	336.5	348.4	230.7
1994 Sep 26 [Mon]	181.8	11.1	-37.4	79.5	37.6	340.4	348.9	229.5
1994 Oct 3 [Mon]	181.9	12.1	-44.2	71.7	30.2	343.6	349.4	228.3

Figure 4. ATTHIST. Given an initial orientation this gives a week by week breakdown of key data, in this case for the Earth-pointing-from-apogee condition longitude 180° latitude 0°. The Sun angle is of greatest importance, and is seen to start at +36°, fall through zero, reaching the nominal limit of -35° in late September, dictating a re-orientation. Other parameters of interest are the percentage solar illumination (100 Cos SA), the Sun's position in longitude (Saz) and latitude (Sel), and the familiar keplerian elements argument of perigee and RAAN.

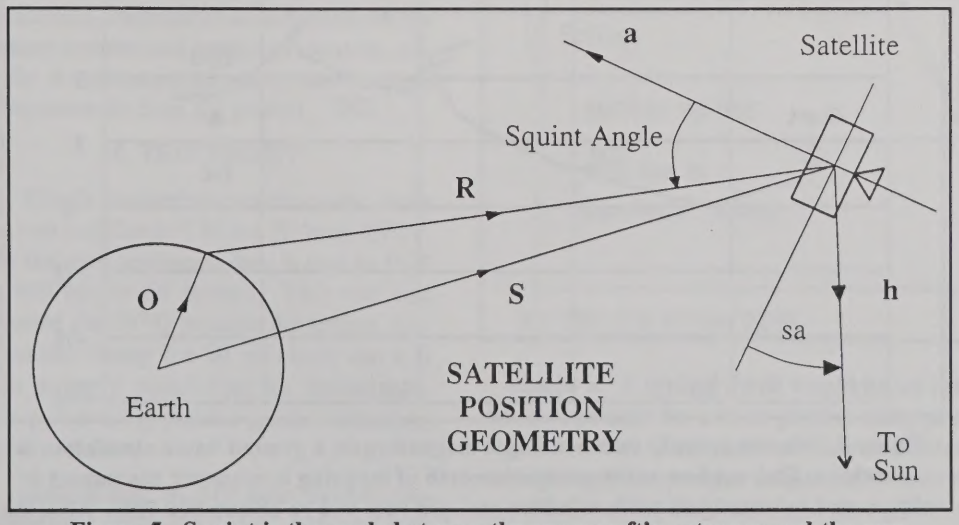


Figure 5. Squint is the angle between the spacecraft's antennas and the user.

```
L QST *** AO-13 TRANSPONDER SCHEDULE *** 1993 May 10 - May 31
Mode-B  : MA   0 to MA 130 !     Omnis MA 250 - MA 60
Mode-BS : MA 130 to MA 180 !<- S transponder; B trsp. is ON
Mode-S  : MA 180 to MA 190 !<- S transponder; B trsp. is OFF
Mode-LS : MA 190 to MA 195 !<- S beacon + L transponder
Mode-JL : MA 195 to MA 210 !        Alon/Alat 210/0
Mode-B  : MA 210 to MA 256 !  Move to attitude 120/0, May 31
Please don't uplink to B, MA 180-190. Interferes with mode S.
```

Figure 5a. Typical transponder schedule.

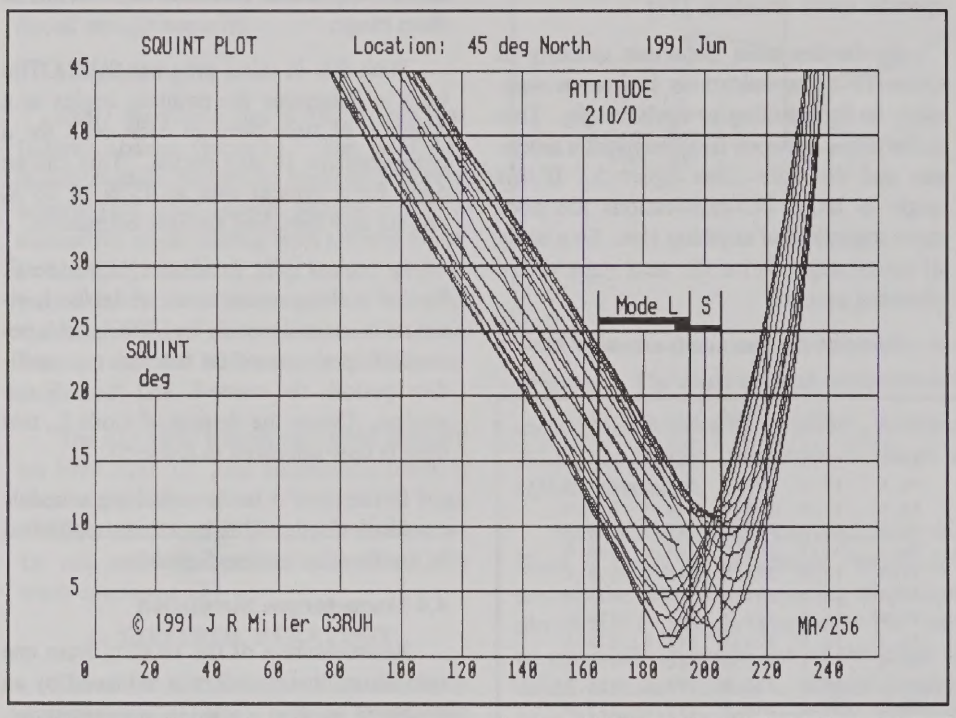


Figure 6. Plots of squint angle as a function of MA are used to devise the transponder mode schedule.

Program MAGSIM output is typified in figure 7. Once again the orientation coordinate system of orbit plane longitude and latitude is used. As the simulation progresses the interim orientation is plotted. Each perigee instant is marked. This example has been exaggerated for clarity.

Across the top of the screen a running display of the most important numbers is maintained. The first line gives time in utc, keplerian elements RAAN and argument of perigee (AP), Sun angle (SA), orbit number and MA. The quantities below the line are columns containing certain vectors expressed in orbit plane (German = Bahn) coordinates. SUN is the Sun's direction, SSV and SV are target and present spin vector as from the spacecraft's on-board magnetorquing algorithm, whereas the column SVr is the real spin vector determined by simulation. Hr, Mr and TQr are the Earth's magnetic field magnitude and direction, spacecraft magnet direction and resultant torque (TQr = Mr x Hr). M-SOLL is the angle on the spin equator between the magnet direction and the Sun. The flight computer uses this to commutate each of the three coils at the right moment.

Over the years this simulation has been refined and calibrated to the point where complex reorientations can be planned and executed with considerable confidence. Errors amount to only 0.2 r.p.m. and a degree or two after a dozen perigee passes and a net movement of 60°. These errors are mainly due to short term variations in the Earth's magnetic field. Finally the program automatically generates the 7 number command sequence that is to be sent to the Oscar-13 on-board computer.

4.5 Other planning programs

ECLIPSE calculates the time and duration of eclipses by the Sun, and is used to determine when temporary changes to the transponder schedule have to be made. MOONECL does the same thing for the Moon. SMOOTH13 takes many sets of NASA keplerian element sets and smooths them, resulting in a secondary set of elements that is free of the short term lunisolar variations and measurement noise that is so readily apparent [5]. About 6 month's past data, typically 20 sets, is processed at once. The smoothed set is used by all the

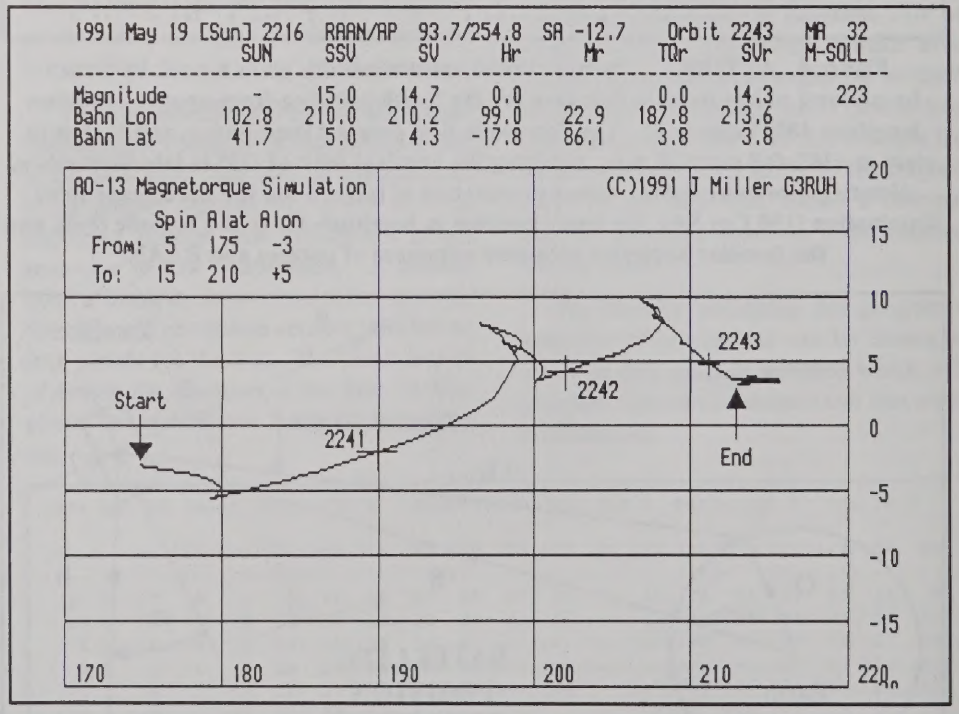


Figure 7. Prior to actually commanding a magnetorque, a ground based simulation is essential to find out how many perigee's worth of torquing is required, the impact of eclipses and to investigate trade offs between spin rate and re-orientation rate. Also, the spacecraft's Earth modelling is a simplification, and simulation can account for this.

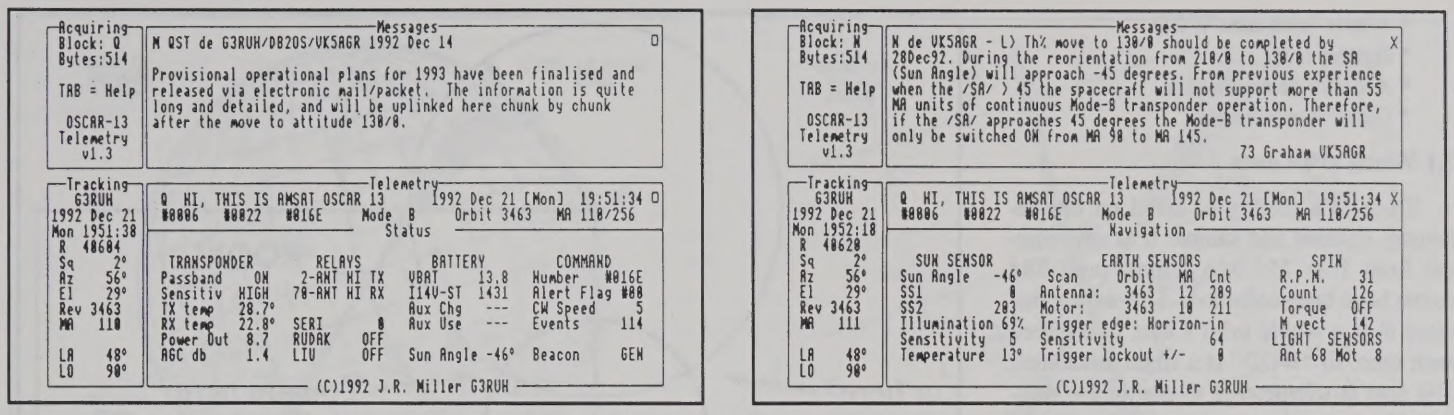

Acquiring
Block: Q
Bytes:514
TAB = Help
OSCAR-13
Telemetry
v1.3
Messages
M QST de G3RUH/DB2OS/VK5AGR 1992 Dec 14
Provisional operational plans for 1993 have been finalised and released via electronic mail/packet. The information is quite long and detailed, and will be uplinked here chunk by chunk after the move to attitude 138/8.
Tracking
G3RUH
1992 Dec 21
Mon 1951:38
R 48684
Sq 2°
Az 56°
El 29°
Rev 3463
MA 110
LA 48°
LO 90°
Telemetry
Q HI, THIS IS AMSAT OSCAR 13 1992 Dec 21 [Mon] 19:51:34
#8006 #0022 #016E Mode B Orbit 3463 MA 110/256
Status
TRANSPONDER RELAYS BATTERY COMMAND
Passband ON 2-ANT HI TX VBAT 13.8 Number #016E
Sensitiv HIGH 70-ANT HI RX I14V-ST 1431 Alert Flag #00
TX temp 28.7° Aux Chg --- CW Speed 5
RX temp 22.8° SERI 0 Aux Use --- Events 114
Power Out 8.7 RUDAK OFF
AGC db 1.4 LIU OFF Sun Angle -46° Beacon GEN
(C)1992 J.R. Miller G3RUH
Acquiring
Block: N
Bytes:514
TAB = Help
OSCAR-13
Telemetry
v1.3
Messages
N de VK5AGR - L) The move to 138/8 should be completed by 28Dec92. During the reorientation from 210/8 to 138/8 the SA (Sun Angle) will approach -45 degrees. From previous experience when the /SA/) 45 the spacecraft will not support more than 55 MA units of continuous Mode-B transponder operation. Therefore, if the /SA/ approaches 45 degrees the Mode-B transponder will only be switched ON from MA 90 to MA 145.
73 Graham VK5AGR
Tracking
G3RUH
1992 Dec 21
Mon 1952:18
R 48620
Sq 2°
Az 56°
El 29°
Rev 3463
MA 111
LA 48°
LO 90°
Telemetry
Q HI, THIS IS AMSAT OSCAR 13 1992 Dec 21 [Mon] 19:51:34
#8006 #0022 #016E Mode B Orbit 3463 MA 110/256
Navigation
SUN SENSOR EARTH SENSORS SPIN
Sun Angle -46° Scan Orbit MA Cnt R.P.M. 31
SS1 0 Antenna: 3463 12 289 Count 126
SS2 283 Motor: 3463 10 211 Torque OFF
Illumination 69% Trigger edge: Horizon-in M vect 142
Sensitivity 5 Sensitivity 64 LIGHT SENSORS
Temperature 13° Trigger lockout +/- 0 Ant 68 Mot 8
(C)1992 J.R. Miller G3RUH

Figure 8. Typical screens from the author's display program. The message blocks are displayed in sequence as they arrive, and can be saved to disc or printer. The lower window can be cycled between Status, Navigation, Power and Temperature data. Windows showing a small square in the top right corner arrived uncorrupted; those with a cross failed their CRCC checksum test and therefore contain errors. One is apparent in the message that begins "N de VK5AGR ".

management programs, rendering them consistent and accurate. The set is also converted into Oscar-13's on-board computer format for direct uploading.

5. THE OSCAR-13 SATELLITE

The spacecraft comprises a number of subsystems [1,3] including:

* On board computer or IHU
* Transponders B, S, (J and L failed)
* Solar/battery power system
* Sun and Earth sensors and SEU
* RUDAK-1 (failed)
* Propulsion system (spent)
* Telemetry system and beacons
* Telecommand system

The on-board computer or IHU (integrated housekeeping unit) orchestrates spacecraft activities. Based on a Cosmac 1802 processor it has 32k of radiation hardened RAM, and input/output interfaces for analogue and digital services. The flight software turns the transponders on and off as directed, switches antennas, monitors the battery systems and navigation sensors. Finally it generates telemetry and accepts telecommands from the ground.

6. TELEMETRY

This is transmitted continuously; there are text bulletins in CW and 50 baud RTTY, but the most important data is sent as PSK at 400 bps or 50 bytes/s. This rate was selected (in 1978) because the system fundamental timing is a 20 ms clock, and it is also properly matched to the limited beacon power using popular ground station receive antennas.

Data is sent in 512 byte blocks, preceded by a 4 byte sync code, followed with a two byte CRCC or checksum and lasts 10.24 seconds. Blocks, interspersed with a few seconds of idle code hex50, consist of engineering data and plaintext messages alternately. A complete description of the telemetry can be found in [3].

Decoders have been available since at least 1984 [6,7]. Audio enters one end, RS232 data comes out the other and the data can be displayed on virtually any PC. This is a routine no-skill operation enjoyed by perhaps as many as 500 operators. Taking telemetry is not the exclusive domain of command stations, and never has been.

The information available is:

* General status
* Navigation
* Power
* Temperature
* Messages

7. INTERPRETATION

Once telemetry has been received it can be analysed in detail if required. This is particularly important during a re-orientation, to ensure that nothing is going wrong, and goals are being achieved. Effort goes mainly into studying:

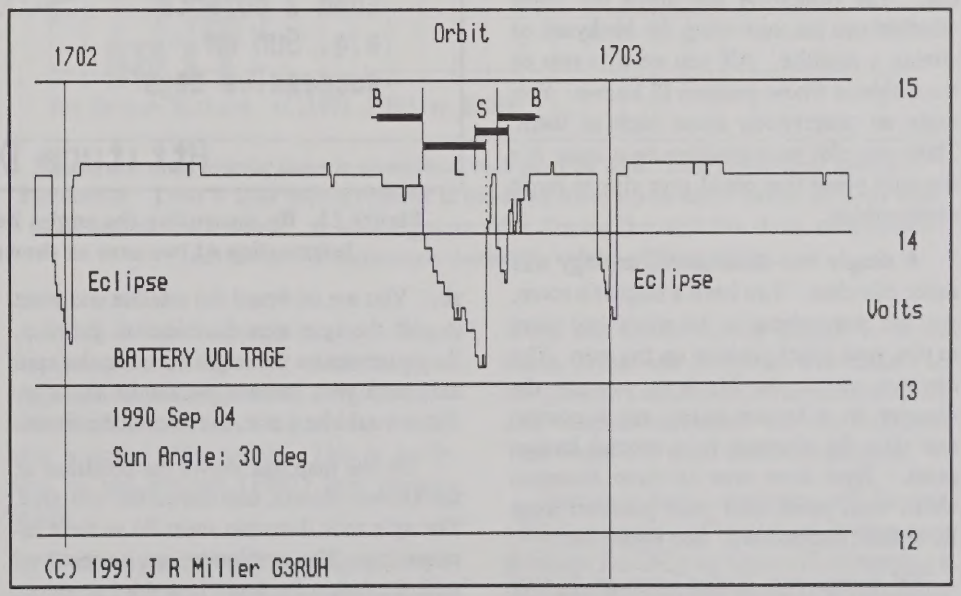


Figure 9. A typical dwell would be on the battery voltage. Here the 384 points of numerical data have been plotted using program WODDISP and give a profile of 1½ orbits activity. This plot has been annotated to show which transponders were in use, and to highlight perigee eclipses. The heavy mode-L loading is apparent. The danger threshold is 12.6 volts, and though not reached, shows why mode-L time was relatively restricted.

* Whole orbit data WOD
* Battery state
* Attitude determination
* General monitoring

7.1 Whole orbit data

There is a facility to dwell on one telemetry channel and sample it at any interval from 1 to 256 MA counts until 384 points have been collected. This means that more than a whole orbit's data is acquired each time, so "WOD" is a slight misnomer. The data is telemetered in one of the message blocks.

Frequent plots such as this have enabled the command stations to predict the exact battery condition under all conditions of transponder loading and solar illumination, and so maximise the facilities on offer at all times.

7.2 Attitude Determination

Oscar-13 carries two optical sensors which are used to determine the satellite's attitude. They are mounted on the end of one arm, and as the satellite spins they scan the spin equator for their respective targets. The Sun sensor measures the Sun angle, (see figure 2), while the Earth sensor responds when the Earth comes into view, generally within the hour or two around perigee.

The art of position finding is centuries old. The principles are much the same whether you are surveying the backyard or aiming a satellite. All you need is two or three objects whose position IS known. You make an observation about each of them. Then you plot your position on a map; it's the only place that could give rise to those observations.

A simple two-dimensional analogy will make this clear. You have a map of a room, you are somewhere in the room and want to plot your exact position on the map. The obvious way to do this is to measure the distance to a known point, say a corner, and then the distance to a second known point. Then draw arcs of these distances about each point, and your position must lie at their intersection. See figure 10.

Of course two circles intersect in two places, and you need to resolve this. Frequently the alternative is unreasonable, but you could easily measure the distance to a third point.

It's just the same with measuring a satellite's position. You have a map of the

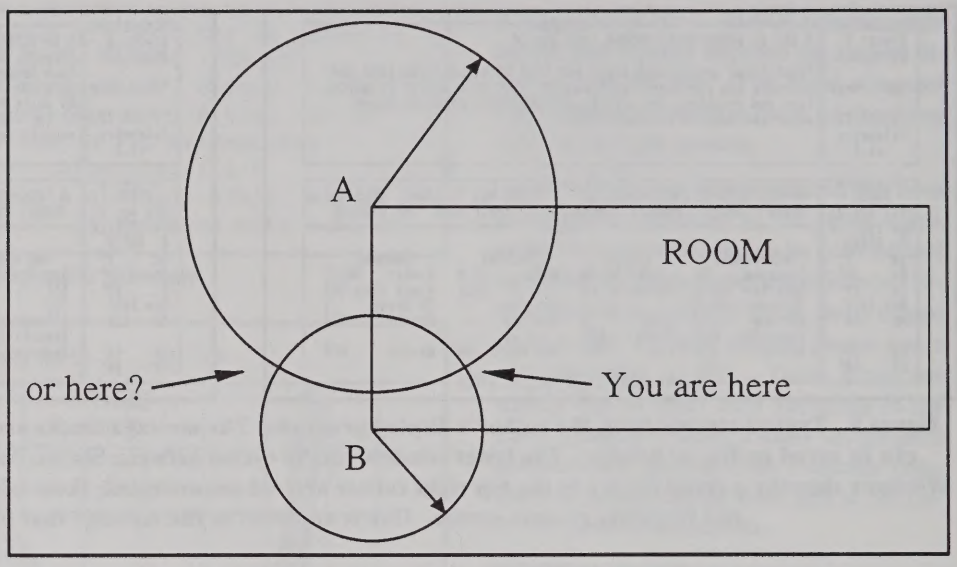


Figure 10. Attitude determination; a two-dimensional analogy.

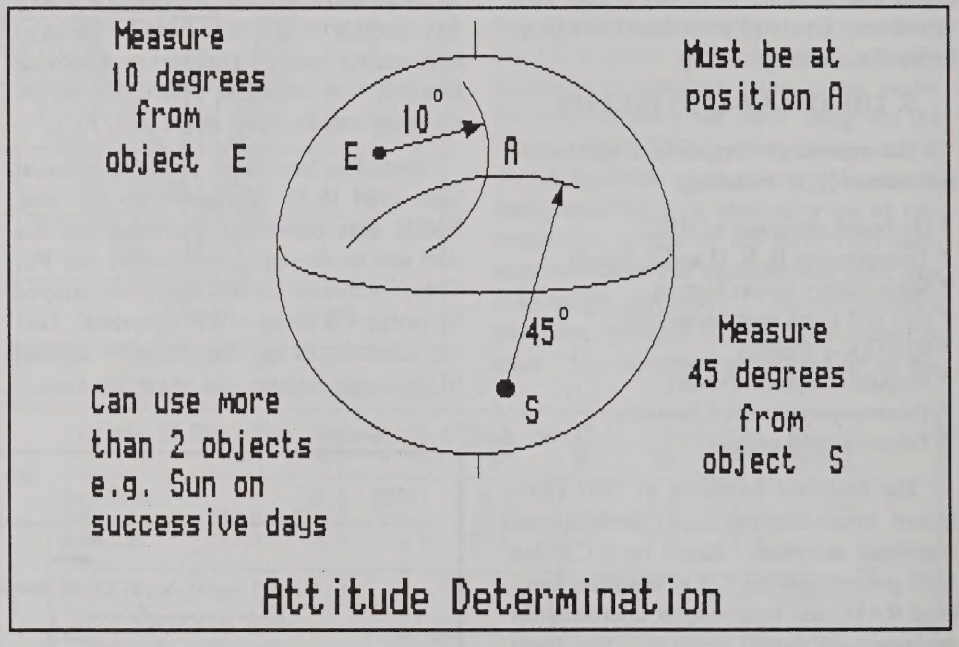


Figure 11. By measuring the angles between a spacecraft axis and two objects, intersection of two arcs as shown locates the direction of that axis.

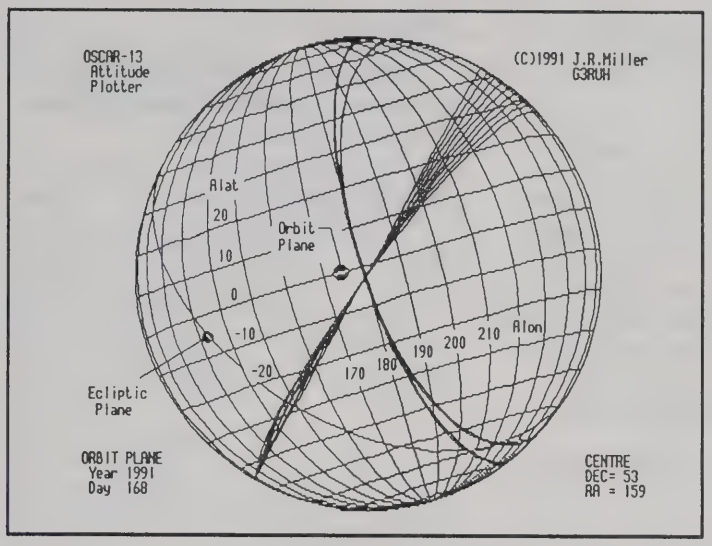
sky. You are on-board the satellite and want to plot the spin axis direction on the map. So you measure the angle between the spin axis and two known points in the sky. These could be a star, the Sun or the Earth.

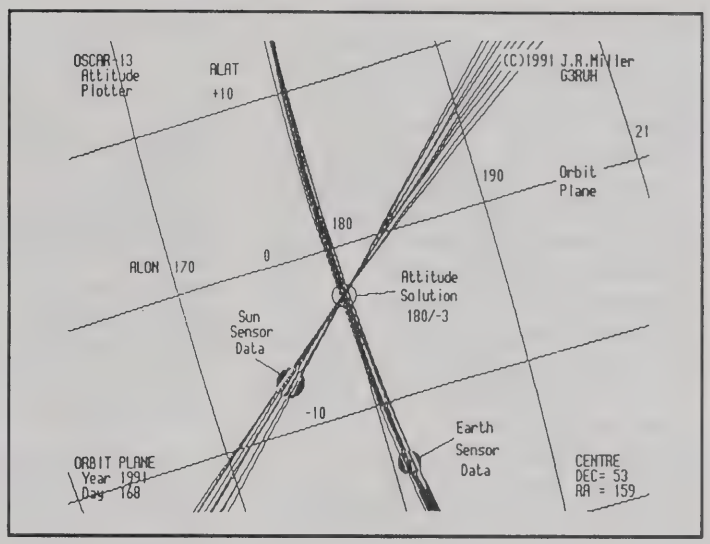
On the map one draws the positions of the known objects, and draws the two arcs. The spin axis direction must lie at their intersection. The ambiguity can be resolved with the help of a body in a third position, or by some reasonableness criterion. This is illustrated in figure 11.

As indicated earlier, Sun and Earth sensors measure the angles for this purpose. Figure 12 shows the resulting plot. The "map" is in orbit plane coordinates, that is longitude 0 to 360, and latitude -90 to 90. A Mercator style square map (e.g. like figure 7) is very clumsy to work with; a spherical presentation is more appropriate since we are entirely concerned with angles rather than distances.

The measured data is superimposed, and although two intersecting arcs would suffice to determine the spin axis direction or attitude, in practice one takes a number of measurements over several days. To make this clearer, figure 13 shows the centre magnified x4. At this scale it can be seen that the data is indeed slightly noisy, hence the need for confirming measurements.

The program which generates these plots





Figures 12 & 13. Oscar-13 attitude determination with program ATTPLOT. The "map" is in orbit plane coordinates, that is longitude 0 to 360, and latitude -90 to 90. Data from Sun and Earth sensors is plotted. Fig. 13 shows the central portion magnified x4.

is called ATTPLOT, and takes as its input date/time and value of Sun and Earth sensor measurements. It takes 4 seconds to compute and draw. Recently the author discovered a means of measuring squint or pointing angle from observations of the S-band beacon doppler shift [8] (the antenna is mounted eccentrically), and this data can also be input and plotted.

Another program called ATTFIX takes the same data set as the plotting program, and computes the least squares solution numerically that is depicted in figure 12 graphically. This is useful for analysing the fine structure and jitter properties of the Sun and Earth sensors, and indeed has been used to calibrate the mounting axis of the Earth sensor itself. The telescope axis has been found to be misaligned by about 2.5° upwards, i.e. toward the antennas, and its two beams are separated by 10.14° rather than the specified 10°. These may seem like insignificant amounts, but small uncertainties in measuring the spacecraft attitude take a disproportionate amount of time (i.e. days) to resolve.

Sun sensor data is quantised to 1 part in 256. This equates to about 1° resolution. Thus a spot measurement is likely to have up to ±0.5° error in it, as well as added random noise. The whole orbit data collection facility helps resolve this. Figure 14 shows the Sun sensor data gathered over a 12 day period. The quantisation and random noise is clearly apparent. A least squares fit is drawn through the data, and allows extraction of extremely accurate values of Sun angle.

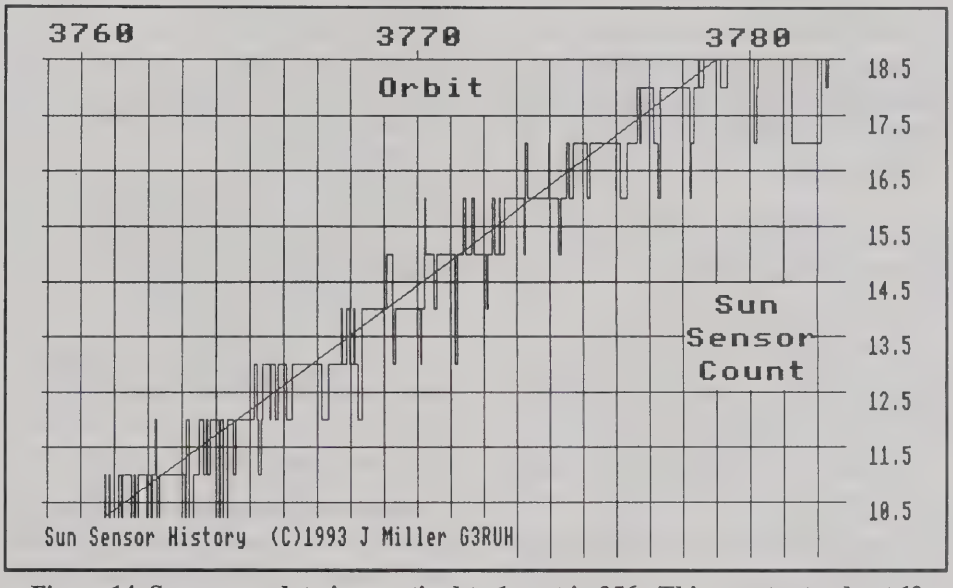


Figure 14. Sun sensor data is quantised to 1 part in 256. This equates to about 1° resolution. Thus a spot measurement is likely to have up to ±0.5° error in it, as well as added random noise. A least squares fit is drawn through the data, and allows extraction of extremely accurate values of Sun angle.

Using this technique, it has been found that the spin axis direction, which by gyroscopic principles ought to be a rigidly fixed direction, does have a tendency to wander over a period of a month. This is attributed to the present (1993) low perigee height.

The many techniques developed for Oscar-10 and Oscar-13 attitude determination have been published, and the interested reader is directed to the references [11, 12, 13]; [15]

8. TELECOMMAND

Oscar-13 is a computer in space; its keyboard and screen merely happen to be on Earth. Thus one composes instructions on the ground, transmits them to the spacecraft, and watches telemetry for the response. This round-trip takes about 30 seconds.

Just as a home computer will be running a program that creates an environment (perhaps BASIC), so Oscar-13 is running a language/environment called IPS, Interpreter Structure for Processes. [4]

8.1 IPS Interpreter

The IPS interpreter offers a plain language environment not unlike FORTH. Instructions are accepted, parsed, compiled

and then executed.

* Essential Primitives are provided. e.g.

Arithmetic 0...9 # + - * /
Relational = < > <> etc
Logical NOT AND OR EXOR BIT
Peek & Poke bytes, words, fields
Manipulate stack (Push Pull Swap Dup)
FOR...NEXT DO...WHILE
REPEAT...UNTIL
An 1802 assembler

* All other objects defined by user

Variables & Constants
Functions/Procedures/Routines

Here are two examples of commands; entering 2 3 + would result in the response 5.

The command sequence:

: SQUARE DUP * ;

defines a new function which will be compiled and ready for global usage. So a subsequent command:

9 SQUARE

would result in the response 81.

8.2 Software Installation

* First the flight computer is reset.
* Next a very short self testing loader is uplinked
* Then the IPS interpreter is uploaded (only 7200 bytes)
* Finally the flight routines are uplinked (36 kbytes).

When the flight routines are running they serve simultaneously:

* 20 ms loop analogue multiplexer] Machine
* 20 ms clocks] code
* Telemetry buffering]
* Spacecraft control. } Interpreted and then compiled code.

8.3 Flight Routines

This is approximately 10 pages of plain language, and is compiled as it is received by IPS. It then totals about 16 kbytes including buffers etc.

At the highest level it is organised around a chain. Calling this is the very last command sent:

```
0 EINH SERVICE      (Battery service,
                     watchdogs)
1 EINH BAKEN-ST     (Beacon sequencer)
2 EINH NAV-ST       (Navigation)
3 EINH MEL-ST       (Memory errors)
4 EINH UL-ST        (Transponder
                     scheduler )
                ( 5 - spare )
                ( 6 - spare )
7 EINH MODE-S-ST    (Mode-S control)
```

The program is "merely" cycling around these eight tasks. Each is defined elsewhere, and of course invokes other definitions. For example, item 2 on the chain, "Navigation start" is defined below, and calls in turn NAVIGATION, SENSOREN and TRQ-ST:

```
: NAV-ST  NAVIGATION SENSOREN TRQ-ST ;

: NAVIGATION  Z-ALT @B Z @B <> DUP Z-MARKE !
  JA? Z @B DUP Z-ALT !B =0
    JA? RECTAS @ KO + RECTAS !
      PERIGA @ KW + PERIGA !
    DANN ORTSDATEN MAGNET @B
    JA? A-CONTROL
    DANN
DANN ;

: SENSOREN Z-MARKE @
   JA? #447 @ SS>BETA BETA !
     #44D #44F JE I 6 + @B
     JA? 0 I 6 + !B Z @ I !
     DANN 2 +NUN
   DANN ;

: TRQ-ST Z-MARKE @
   JA? E-FLAGS @ #14 UND >0  Z @
     MZEITGRENZE @ = ODER
     JA? 0 M-EIN !
     DANN Z @B 32 + #FF UND 64 < M-EIN @
        UND 1 UND MAGNET !B
   DANN ;
```

8.4. Commanding

Day to day commands are required to update Message blocks (which can be read on the beacons in PSK, RTTY and CW), invoke magnetorques, check sensors, invoke WOD data collection, change transponder mode schedules and so on. Occasionally 0 TRANSPONDER is needed!

Commanding is a very small part of Oscar-13 management. It is not always straightforward. The 435 MHz command uplink is interfered with by radar, and man-made noise invariably ruins 145 MHz downlink telemetry, especially at poor pointing angles and at maximum range. Mode-B commanding is tiresome at best.

Fortunately the 1269 MHz uplink is still available and needs only a few watts e.i.r.p., and the 2400 MHz S-band downlink is very strong on compact antennas [9,10] and error free. So provided the mode-S facility is exercised daily, which it is, an excellent command link is assured.

8.5 Reliability

Crashes are very infrequent. One initial load, and five reloads have taken place as follows shown in figure 15.

Load	From	To	Total Commands	Life Days	Rate Comms	Crash Notes
1	1988 Jun -	1989 Oct 09	1173	480	2.44	*
2	1989 Oct 09 -	1989 Oct 28	390	19	20.53	rt
3	1989 Oct 28 -	1989 Dec 10	224	43	5.21	*
4	1989 Dec 10 -	1991 May 13	759	519	1.46	pt
5	1991 May 13 -	1992 Jan 29	248	261	0.95	rs
6	1992 Jan 29 -		612	570	1.07	(o)
		Total	3406	1892	1 80	

Notes
* reason unknown - probably radiation hit on CPU
rt after intensive RUDAK testing; probably an induced mistake
pt investigation of navigation coding error induced a "poke" with its address and data transposed.
rs reset command inadvertently sent.
(o) as of 1993 Aug 21
A reload uses 70 commands.

Figure 15. Data on AO-13 Reliability

8.6 Coding

The COSMAC 1802 IPS interpreter was designed and implemented by Dr. Karl Meinzer DJ4ZC [4] in the late 1970s. The flight software was also written by Dr. Meinzer, and has been edited and added to by Peter Guelzow DB2OS and author G3RUH.

9. THE FUTURE

Oscar-13 management has essentially stabilised, and a regular diurnal rhythm is well established. The spacecraft is "calibrated" to a high degree, and is extremely reliable.

It is now well known that the orbit is slightly unstable in that the eccentricity oscillates, figure 16. In 1996 perigee passes will strike the atmosphere causing the orbit to decay rapidly. This has been documented by several authors; [5] contains a full bibliography. It will be an interesting period.

10. CONCLUSION

Many command stations have contributed to Oscars 10 and 13 management at one time or other. These include DB2OS, DJ4ZC, DK1YQ, G3RUH, VE1SAT/VE6, VK5AGR, W0PN, W3GEY, ZL1AOX. Many more potential command stations work or have worked behind the scenes. Some have pulled out to work on other satellites or in other fields. For some their work is over (e.g. RUDAK specialists), or they simply retire. A thousand or more hours a year is a lot to give.

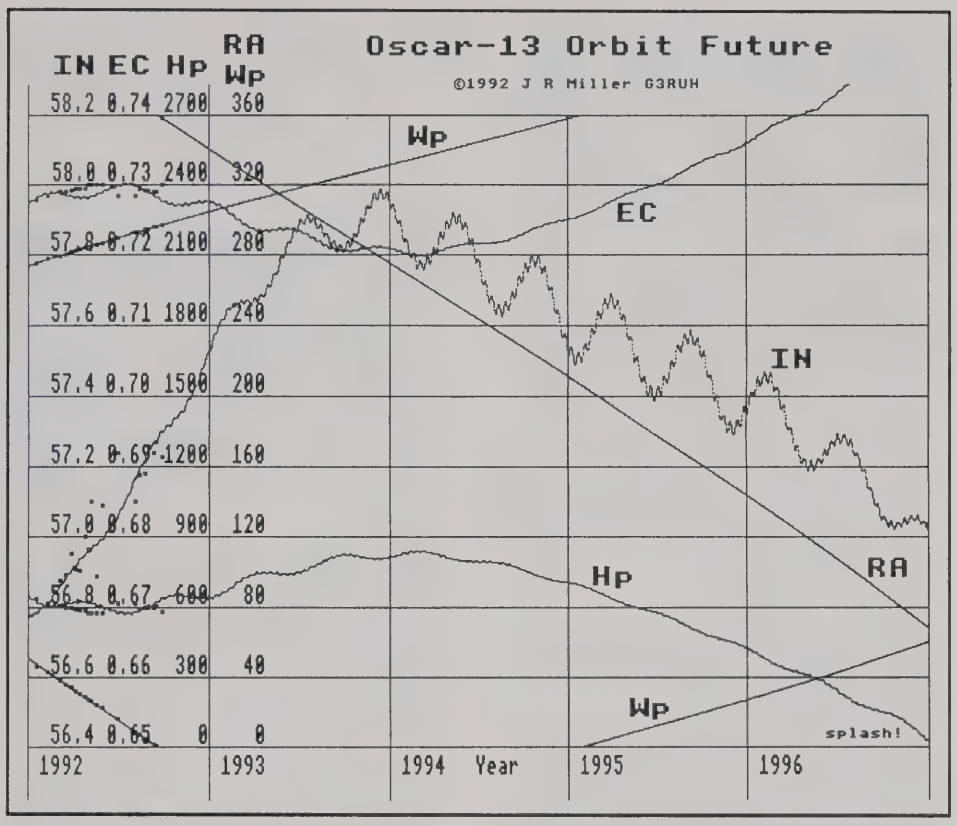


Figure 16. The orbit is slightly unstable in that the eccentricity oscillates. In 1996 perigee passes will strike the atmosphere causing the orbit to decay rapidly. This has been documented by several authors; [5] contains a full bibliography. Hp is perigee height.

The present day command team consists of DB2OS, VK5AGR and the author G3RUH. Having a transmitting station in each hemisphere is important, but geographic location is otherwise irrelevant. In fact it is quite possible to have non-transmitting command stations, since others can do the actual uploading.

The core team is in daily and immediate contact via telephone, fax and e-mail. Contact with the user community is via similar routes, the post and by listening to the transponders. All significant decisions are made jointly, and by common consent can be vetoed by the others.

Anyone can do this job if they show the level of commitment typified by the people whose callsigns are listed above. These folks are self-motivated, self-trained, self-starting and self-sustaining.

There is absolutely no "how-to" manual, and no training course. They have a strong inquisitive streak, and an ability to work things out from scratch unaided. There is no glamour, and no "power". Far from it. They do it because it is interesting.

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CREDO

Discovery is easy; the difficulty is to acquire what we discover.

- Roberto Gerhard, composer 1896-1970.

Microsat Operation With the PK-232

by Howard Sodja, **W6SHP**
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4317 Santa Rita Rd
El Sobrante Ca. 94803

Editor's Note: This article first appeared in Oscar News, published by AMSAT-UK and appears here courtesy of that publication and its editor. In addition to covering some of the ideosyncracies of the PK-232, this article also contains a great deal of information about digital satellite operation in general.

Operation on the Microsats is both rewarding and challenging. One of the challenges has been to get my PK-232 TNC to work with the software developed for the Microsats. With a terrestrial BBS all the software controlling the file server is run on the BBS's computer. Your TNC needs only needs to speak "AX.25 ASCII" to connect and then respond to the prompts of the BBS's software. With the Microsats every user runs this controlling software on their own PC, with the data sent in binary form. This frees up valuable processing time on board the Microsats on those brief LEO passes. The Microsats can spend most of their processor time sending data, while your PC keeps track of when you last connected (for directory updates), and what packets have or have not been up or downloaded. Binary data transfer is more efficient. This simplifies "computer to computer" communication between your PC and the Microsat CPU, and permits the transfer of compressed files, programs, and earth photos from UO-22 and KO- 23.

All this magic is performed by two complementary programs, PB.EXE for broadcast requests and reception and PG.EXE for file uploading (1). This software was developed by the Microsat team for the PC running MS-DOS with a TAPR TNC-2. Herein lies the root of the problem we PK-232 owners face. Although most TNC-2 commands were the same with the PK-232, there were enough differences in the command structure and default EPROM settings to leave PK-232 owners with an empty screen when the first Microsats were switched from ASCII to binary transmissions in early 1991.

PB and PG requires that your TNC be switched into the KISS mode for the "transparent" handling of the binary data flow. Unfortunately the EPROM available with the early PK-232's did not implement the KISS command the same as TAPR's TNC-2. This problem became a hot topic of conversation on the West Coast 75 Meter AMSAT net until Dave, KI6QE came up with a list of additional commands that switched the PK-232 into a "TNC-2 compatible" KISS mode. Also some additional parameter settings were needed to run PB and PG. An ASCII file with these added commands needed to be uploaded to the PK-232 with a modem program before you ran PG or PB.

We soon learned that the PK-232's "25June88" updated EPROM implemented the KISS command the same as the TNC-2. Once I upgraded to this EPROM I was able to eliminate the PG/PB preloading configuration file by adding the non-KISS PK-232 commands from my preloading file into PG's and PB's TNC configuration file, PG.TNC (table 1a). Now I only needed to wake up my PK-232 (with the "*" autobaud command) before running PG, which automatically uploaded PG.TNC to my PK-232.

All went well for PK-232 Microsat users until early 1992 when a new much improved version of PB/PG was uploaded on UO-22, the 9600 baud bird. All UO-22 users were aware of the bottleneck created by the need for every user to wait his turn to log onto one of the two uplink channels to download (in PG's "connect" mode) the same directory information everyone else was waiting to download. The new PB software now broadcasts this directory information so all PB users can copy directory listings while they are simultaneously downloading requested broadcasted files.

I had worked UO-14 and UO-22 with my old PB/PG software. When I tried the new PB (920224M) and PG (920225) programs I was shocked to find nothing was being copied off the bird. I put out a call

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for help on all the Microsats, seeking anyone who had the PK-232 working with this new PB/PG.

Hardware tests

The "eye pattern" test is used to evaluate a modem's received signal quality. The downlink signal (after the modem's rx filter) is displayed on an oscilloscope, where it appears as an "eye" (figure 1). This test was invaluable for me as I could see if modifications I was making to my rig and modem were improving my 9600 baud downlink signal quality from UO-14. I installed a miniature stereo jack that is wired to my modem's "eye pattern" test points to simplify this test.

At first my UO-14 eye pattern was fuzzy and my throughput disappointing. Removing C82 in my FT-736R and changing C25 to 1 Mf in my G3RUH modem noticeably sharpened this pattern, opening up the eye and improving my throughput. I also observed that when my throughput was poorer than normal with a strong downlink, I would also have a poor eye pattern. This can be caused by inaudible QRM or downlink phase-shift distortion, which occasionally slows everyone down on the Microsats.

Although the statistical probability of my having a 9600 baud hardware failure the same time UO-22 had a new software upload was remote, it could not be overlooked. However, my modem's eye pattern was open, crisp and steady, so I knew I was receiving a good downlink signal.

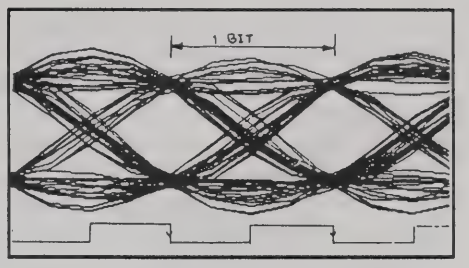


Figure 1. 9600 baud "Eye" diagram, used to evaluate signal quality to your modem. Reprinted from the G3RUH modem construction manual, by James Miller.

My output tested good up to the internal modem loopback test. But I had no one near by with whom I could make an external 9600 baud RF link. Buzz, WH6I, suggested I connect to myself by transmitting on 2 meters, full duplex, and receive my 70 cm third harmonic. As overloading can be a problem, I began with my transmitter power at minimum and found that less than a watt of power resulted in a welcomed "connect". Now I knew I had a software problem.

The 9600 baud solution

My query was finally answered by Niels, VK2BKQ, who was still using the old "pre-Kiss" 1987 EPROM. By uploading an ASCII configuration file (table 2) to the PK-232 with a simple modem program before running PB or PG he has been able to work UO-22 with the new PB/PG software. These commands are a slight variation the ones Dave, KI6QE developed earlier.

By now I had upgraded to what was at the time the latest PK-232 "01Aug91 MBX" EPROM. I was able to eliminate all of Niel's KISS configuration commands which are needed to get his PK-232 into a TNC-2 compatible KISS mode. I added the remaining configuration settings to PG.TNC (table 1b) to avoid the hassle of uploading a separate configuration file before running PB or PG. Unlike earlier versions of PB, the new version of PB did not upload PG.TNC to the PK-232, so I had to write the following batch file to run PB:

```
pg -q
pb
```

This batch file runs PG, which uploads PG.TNC to my PK-232. The "-q" quits PG, leaving the PK-232 all set for PB. PB is then loaded and run.

I wrote another batch file for use if I want PG to upload files before exiting to run PB. I just changed the first line to "pg -u -q". The -u (upload) and -q (quit) batch file commands will only work with PG.EXE dated 9 September, 1991 or later. You can add other batch file commands after pb if you would like to do any post pass batch file processing of your downloaded files. With the number of files you can download at 9600 baud it is convenient to have batch files copy your downloaded files (*.DL) to a desired subdirectory, extract the files and delete files no longer needed automatically when you quit PB.

You can quit one satellite and run the batch file for the next one you want to copy without going back to the modem program you use to "wake up" and initialize your PK-232. But on occasion the PK-232 may lock up after exiting PB. Normally when your batch file runs PG again you will see your PG.TNC commands scroll by. If PG hangs at the start of this scrolling, simply turn your PK- 232 off and back on. The upload will resume and PG and PB will run fine.

Table 1a

RETRY	10
FULLDUP	ON
FRACK	6
MAXFRAME	1
PACLEN	130
PACTIME AFTER	10
my	w6shp
hb	1200
xon	$00
xoff	$00
start	$00
stop	$00
dcd	on

Table 1b

RETRY	10
FULLDUP	ON
FRACK	3
MAXFRAME	1
PACLEN	130
PACTIME AFTER	1
my	w6shp
hb	9600
xon	$00
xoff	$00
start	$00
stop	$00
dcd	on

Table 1a. PG.TNC file for PK-232s with an EPROM that fully supports KISS (25JUNE88 and later), running PB and PG version 920224M or later. These settings are for the 1200 baud Microsats. Lower case commands are specifically for the PK-232. Read the PB, PG and PK-232 documentation for details on all these commands and for suggestions on fine tuning some parameters to maximize throughput for your system. Initialize your PK-232 for 9600 baud, 8 bit, no parity, 1 stop bit (8N1).

Table 1b. PG.TNC file for the 9600 baud Microsats.

Battery Back-up

In the early days of trying to get the PK-232 to work with PB and PG, PK-232 owners had problems with PB and PG hanging unexpectedly. Word soon got out that this problem could usually be solved by removing the battery that backs up the PK-232's memory when the TNC is switched off. Other programs we were running with the PK-232 were apparently throwing PK-232 soft switches that sometimes conflicted with PB and PG.

When you turn off your PK-232 to clear it's memory, you must wait several minutes before restoring power. If you want to clear the PK-232's memory quickly you must turn off the 12 volts supply and turn the PK-232 "on" for at least a minute.

Besides providing you with "fresh" EPROM default settings every time you turn on the PK-232, removing the battery eliminates the danger of your PK-232's motherboard self destructing from leaking battery electrolyte should your backup battery leak. I have heard of two cases of this happening.

Modem Interfacing

Unfortunately the external modem connector on the rear of the PK-232 does not have the clock output needed by the 1200 baud PSK and 9600 baud FM Microsat modems. TAPR (2) came to the rescue with their "Modem Disconnect Board" which makes surgery on the PK-232's motherboard unnecessary. With this simple TAPR kit you just remove U7 from the PK-232's motherboard and insert the small TAPR board into U7's IC socket. The Z8536 chip from U7 is then inserted into the IC socket on the TAPR board. Then you add a 20 pin female connector to your external modem cable and connect it to the 20 pin male header on the TAPR board and you are all set. The TAPR board provides your external modem with a "X 32" clock. If you need a "X 16" clock speed, simply disconnect the board's pin 11 connection and solder this cable line to U8's pin 11.

This external modem cable enters my PK-232 through a "U" notch I filed in the DB25 connector opening on the rear cover. I also wired a "Y" branch onto this cable so I could connect both 1200 baud and 9600 baud modems to this port. Just be sure to wire switches in your modems so you can take both external modems off line and still use the PK-232's internal modem by shunting the modem lines needed by the PK-232's internal modem. The TAPR 1200

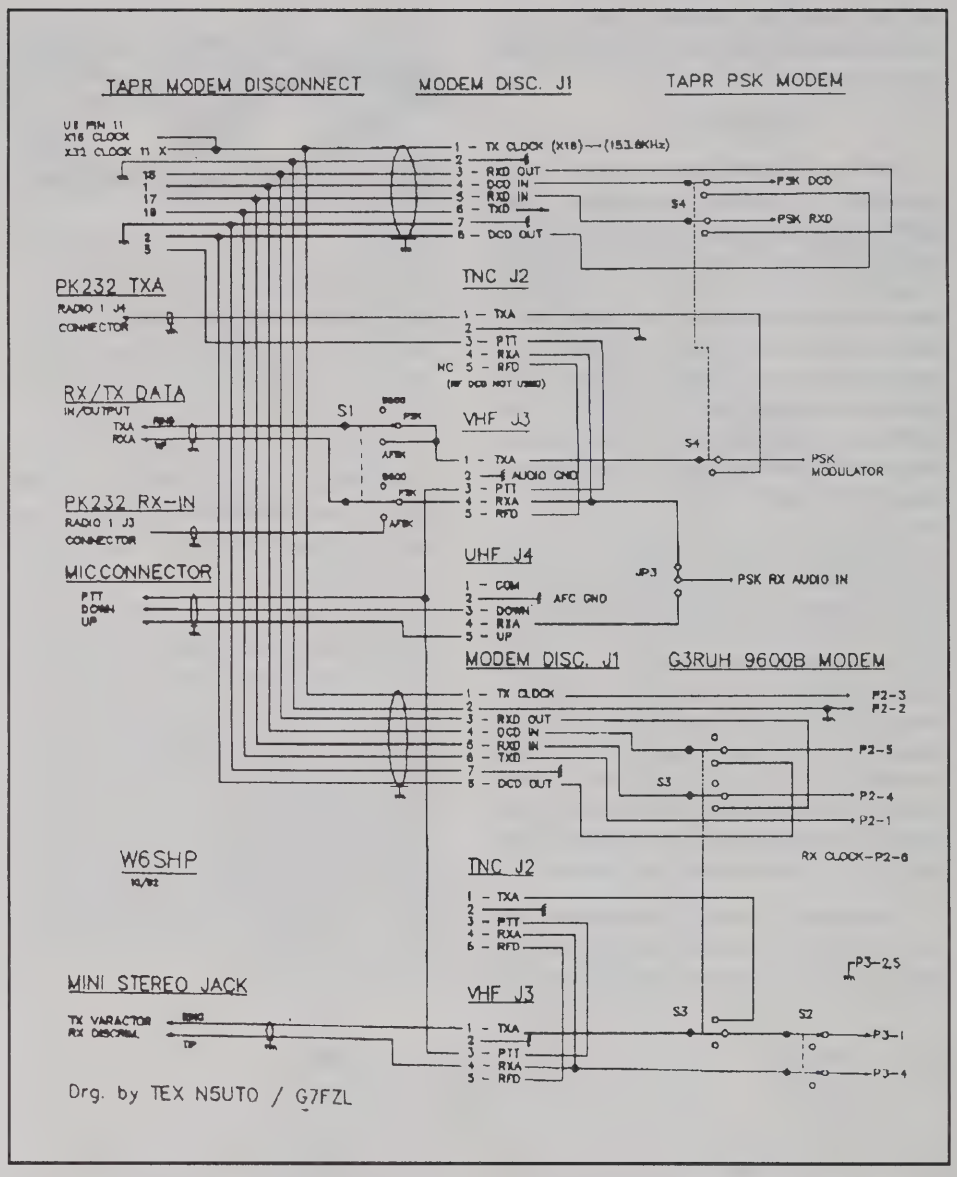


Figure 2. Interconnections between my PK-232's TAPR Modem Disconnect Board, 9600 baud G3RUH modem and TAPR 1200 baud PSK modem. Switching permits selection of either external modem or the PK-232's internal modem (shunt). S1 (DP3T video/audio switch with RCA connectors) switches modem audio, S2 (DPDT) switches 9600 baud audio on/off, S3 (3P3T) switches the 9600 baud modem lines on/off/shunt, and S4 (3PDT) switches PSK lines on/shunt. (Reprinted from OSCAR News, August, 1993).

baud PSK modem has this shunt switching in its design. A high quality triple throw video/audio selection switch with RCA connectors switches my transmit and receive audio lines to my PK- 232's internal AFSK, external 1200 baud PSK or 9600 baud FM modems (figure 2). When I built my G3RUH modem I used the same DIN connectors and pinouts as used in the TAPR PSK modem to simplify my cabling and troubleshooting.

Transmitter and Receiver Interfacing

Connecting your Microsat modems to your receiver and transmitters is a subject too large for this article. But a few general points are worth mentioning. Attempting to use your microphone input and speaker output for your PSK input and output will work, but your throughput will be disappointing. You must inject and extract your modem's input and output past the pre-emphasis and de-emphasis circuits that shape your audio. Remember to turn your mic gain all the way down as any audio from your microphone will trash your digital signal.

Newer rigs have digital data inputs that work fine for PSK, but not for 9600 baud

FM. Here minor surgery is needed, as you must inject your modem's output into the FM varactor, and pick up your received signal from your discriminator. Use shielded cable. Look for the first resistor after these devices and solder your center wires to the exposed resistor wire farthest from the varactor and discriminator, and the shield to the nearest ground point. This will usually work if you have a "true FM", and not a phase modulated rig. If you do not have a deviation meter, you can use a scope for adjusting your digital deviation. Adjust your modem's output to your varactor injection point for the same transmitter PEP output that you get with 100% modulated FM audio. This should be close to 3 KHz deviation, assuming your rig's FM deviation is properly adjusted.

Although a wide IF filter will make 9600 baud throughput better, many of us want to retain our stock narrow IF filters. I have found that tuning both my uplink and downlink signals for the doppler shift improved my 9600 baud throughput. I recently built the TAPR Trakbox (2) to automate this doppler tuning, and have been rewarded with the best throughput I have ever had on 9600 baud.

If you are not sure how to make your digital interface, and your rig's manufacturer is of no help, read PACSAT Beginners Guide (4) and check into one of the AMSAT nets in your area. Those of us who have solved these problems are always willing to help others struggling to get on the Microsats.

Throughput Survey

The PK-232's maximum terminal communication speed is 9600 baud (TBaud). Many have questioned whether TNCs with higher terminal speeds would have higher throughput on the air at 9600 baud (HBaud). I took a small informal survey among nine Microsat friends and found no hard statistical evidence of improved throughput for TNC's running a terminal baud rate of 19200 baud on UO-22 and KO-23 (3). PB documentation indicates this might be a problem with a slow PC or if you are running TSR (Terminate and Stay Resident) programs that slow down your PC.

Two stations believed that they improved throughput by abandoning the PK-232 for 19200 baud terminal speed TNCs. But neither had throughput statistics comparing the PK-232 to their 19200 TBaud TNC to confirm this. Their 9600 baud PB.LOG throughput with a 19200 TBaud TNC was comparable to 9600 TBaud users.

What I did notice was improved throughput for those with higher gain antenna systems and with automatic doppler tracking. I have found this to be true with 1200 baud PSK on LO-19 and AO-16 as well. This conclusion is based on my own experimentation and confirmed by my admittedly small sample of station logs.

On the 1200 baud Microsats I find that the slightly increased throughput with my beams is not enough to justify the wear and tear on my rotors unless the pass will never go above 20 degrees. But on the 9600 baud birds the throughput drop with my omnidirectional Lindenblads is unacceptable even on high passes. Even with my beams I need to monitor my signal strength at 9600 baud so I can change polarization when needed to keep my signal strength (and throughput rate) up. PB displays your throughput speed and bytes copied on the bottom of PB's screen so you can see how you are doing throughout a pass.

conm	conv	ppers	on
pe	128	raw	off
xflow	off	start	$00
stop	$00	xon	$00
xoff	$00	hpoll	on
kiss	off	mon	on
conok	on	my	vk2bkq
retr	8	fu	on
tx	30	mfrom	all
mt	none	hb	9600(use hb 1200 for the 1200 baud Microsats)
mon	on	conok	on
conmode	transv		
dcd	on	ppers	on
raw	on	hpoll	off
kiss	on	host	on

Table 2: Niels, VK2BKQ, using an old 1987 EPROM, uploads this file to his PK-232 prior to running PB or PG with a simple communications program set for 9600 baud, 8N1.

PB's "e: count"

PB also displays your packet corruption errors as an "e: count". It is not unusual to get a few "e: counts" if you are using PB's "view directory" functions during a pass. But if you get "e: counts" when you are only downloading you have a problem.

Two stations reported having this problem until offending TSRs were removed. Another station had problems with PB until he upgraded from a slow XT PC to a faster AT PC. The slowest PC that provided trouble free 9600 baud operation among the survey participants was a 12 MHz AT PC clone.

More Information

I have only discussed a few aspects of getting on the Microsats with a PK-232. For additional information I suggest you get the PACSAT Beginners Guide (4) and the Satellite Experimenter's Handbook (5). Past issues of AMSAT Journal (6) and AMSAT-UK's publications (7) are other good sources for finding practical "how to" information.

References

1. PB.EXE, PG.EXE and related programs are available from AMSAT-NA, 850 Sligo Ave. #600, Silver Spring Md 20910 (telephone 301-589-6062). Written by Jeff Ward, G0/K8KA, University of Surry, Guildford, Surrey, U.K.

2. TAPR (Tucson Amateur Packet Radio Corporation), 8987-309 E. Tanque Verde Rd. #337, Tucson Az 85749-9399 (telephone 817-383-0000).

3. Comments, station and throughput data from K6OYY, KB5MU, KI6QE, N3CPX, W6SHP, WH6I, WB5EKW, WB6LLO and VK2BKQ.

4. The PACSAT Beginner's Guide. Published by and available from AMSAT-NA.

5. The Satellite Experimenter's Handbook, 2nd edition, 1990, by Martin R. Davidoff, K2UBC. Published by the ARRL and also available from AMSAT.

6. AMSAT Journal, AMSAT-NA's bimonthly publication for all members.

7. AMSAT-UK, 94 Herongate Road, Wanstead Park, London E12 5EQ, England (telephone 081-989-6741) Contact them for a list of their publications.

The Making of AMSAT's New Phase 3D Video

by Keith C. Baker, KB1SF

Along with the technical job of designing and building the Phase 3D satellite goes another, equally challenging, yet no less important task. That task is raising the necessary funds to enable completion and launch of the spacecraft. Spell that: "P-U-B-L-I-C-I-T-Y."

Very early in the Phase 3D program, the importance of this daunting task became painfully apparent to the AMSAT leadership at the time. So, back in 1991, a series of discussions ("brainstorming sessions") were conducted by the then AMSAT President Doug Loughmiller, KO5I, along with the current AMSAT President, Bill Tynan, W3XO. These two gentlemen were soon joined by Roy Neal, K6DUE and Bill Pasternak, WA6ITF (of Westlink fame). Their overall goal was to develop a strategy to insure the necessary resources would be available to bring the Phase 3D program to fruition.

Out of these sessions came a number of ideas for bringing the Phase 3D project to the attention of hams and others who might be pursuaded to lend their financial support. One of Bill Pasternak's suggestions included the production of a video tape that could be played at hamfests and other amateur radio (as well as non-amateur) gatherings. An added benefit of this approach was that the video could also be used to help generate interest in the program (and, hopefully, stimulate DONATIONS) from both corporations and foundation officials.

These initial discusssions led to more concrete proposals. Bill Pasternak suggested that retired Senator Barry Goldwater, K7UGA, would be an excellent spokesperson for the program. Roy Neal, an accomplished NBC Television Network professional, having just retired from the network a few years ago where he specialized in covering science and space events, volunteered to be the video's host. This would be particularly useful, as many Hams are already familiar with the outstanding series of videos hosted by Ray on the various facets of Amateur Radio, including the SAREX program.

During a January 1992 visit with Senator Goldwater at his Scottsdale, Arizona home, Doug Loughmiller and Bill Tynan were able to secure his both eager and gracious offer to participate. This event set the stage for actual taping to begin in the Summer of 1992.

As this effort was going on, another key ingredient of the publicity project was coming together in Florida. It involved the construction of a one quarter scale model of the Phase 3D spacecraft by Stan Wood, WA4NFY. The results of Stan's superb handiwork provided an outstanding representation of the spacecraft that was later shipped to Scottsdale for use as one of the centerpieces of the video...and just in time for the initial "takes". Charlie Justiniak, W7GBI, an AMSAT member who resides in Scottsdale, volunteered to receive the model as well as do some of the other legwork involved with setting up the "shoot".

Bill Pasternak donated his expertise as Producer/Director for the production and also enlisted the aid of Forrest Oden, N6ENV, to handle the myriad of technical details. In addition, Bill secured the services of Joe Schroeder, W9JUV, the former Editor of HR Report, to assist in the production.

The result was an outstanding video production that was successfully used at a number of functions and fund-raising activities. However, soon after the tape's final release, an announcement by the European Space Agency that Phase 3D, as then designed, had no hope of being launched. This unfortunate turn of events caused a major redesign of the spacecraft's structure. It also meant that much of the original video the team had obtained with Senator Goldwater was now hopelessly out of date!

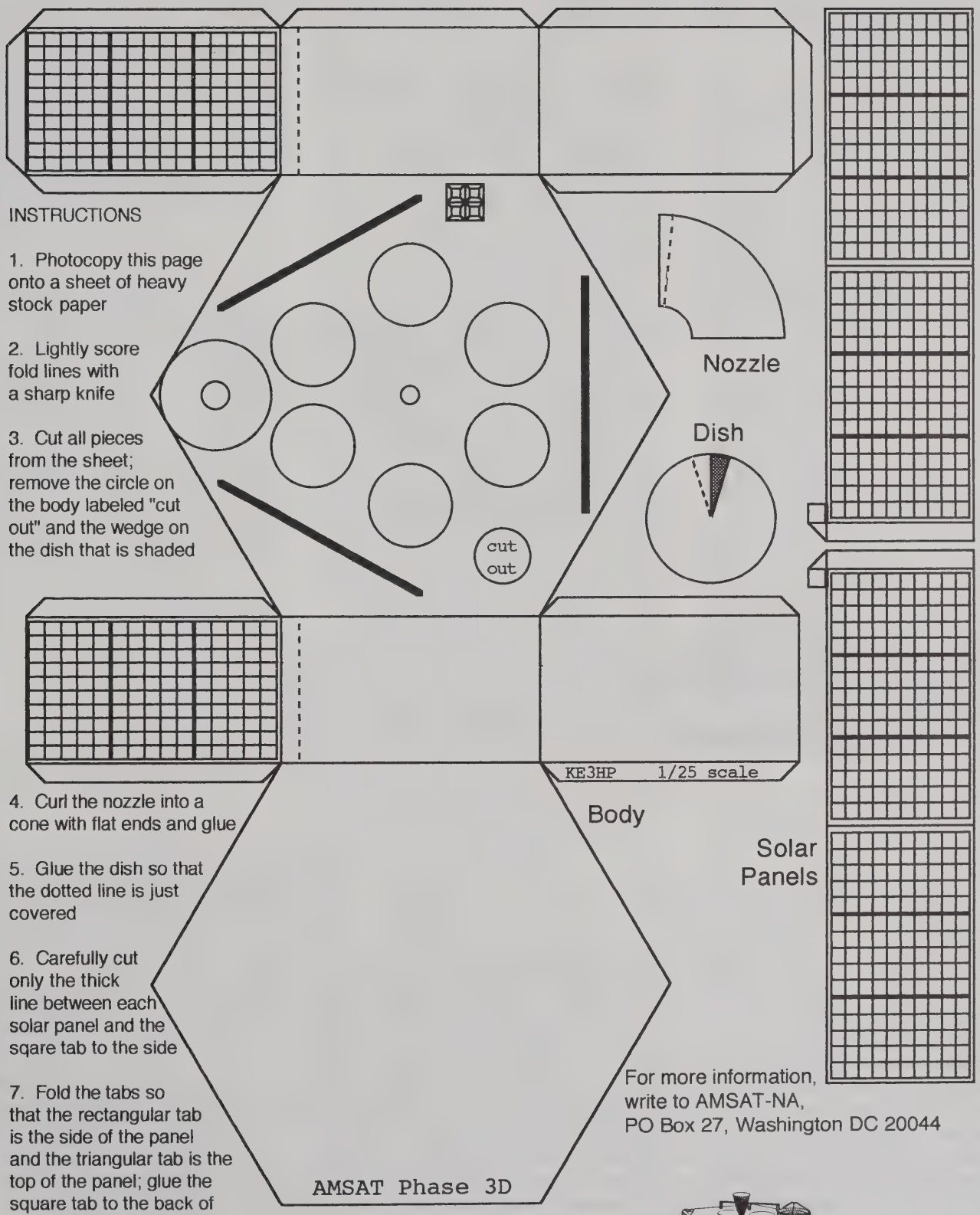
However, rather than mourn the loss of a very valuable fund raising tool, the Phase 3D publicity team set to work to bring the old video in line with the then emerging design of Phase 3D.

Stan Wood agreed to construct an updated version of the Phase 3D model. This was no small feat, in that Stan eventually went through not one, but several preliminary spacecraft models as the redesigned Phase 3D configuration evolved. Next, Senator Goldwater agreed to a "reshoot" of updated video at his Scottsdale hamshack, and Roy Neal offered to provide an updated audio track to match the new video frames.

The new Phase 3D video has now been completed and will soon be available for loan by sending a self-addressed 7¼ x 11" bubble cushioned mailer and $2.90 postage (U.S. only) to return a VHS video tape to you via First Class mail) to AMSAT-NA Headquarters. Ask for the "Phase 3D Promotional Video". Borrowers are encouraged to make their own copies for use in promoting the project. Also available from Headquarters, as a part of this package, is a new set of PHASE 3D Fact Sheets describing the history and current status of the program. These are also suitable for local reproduction and distribution both within and outside the Amateur Radio community.

The new tape will be a valuable addition to your video library. When combined with the new Phase 3D Fact Sheets, the resulting publicity package becomes a superb way for you to spread the word about the importance of the Phase 3D project. Reserve your copies of the Video and Fact Sheets from Martha at the Headquarters ...Today!

Senator Goldwater looks over Stan Wood's (WA4NFY) latest model of Phase 3D in the Senator's hamshack. *(KB1SF Photo)*



INSTRUCTIONS

1. Photocopy this page onto a sheet of heavy stock paper

2. Lightly score fold lines with a sharp knife

3. Cut all pieces from the sheet; remove the circle on the body labeled "cut out" and the wedge on the dish that is shaded

4. Curl the nozzle into a cone with flat ends and glue

5. Glue the dish so that the dotted line is just covered

6. Carefully cut only the thick line between each solar panel and the sqare tab to the side

7. Fold the tabs so that the rectangular tab is the side of the panel and the triangular tab is the top of the panel; glue the square tab to the back of the panel.

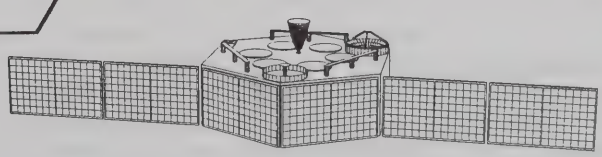
8. Fold the body into shape and glue all tabs in place

9. Glue the dish into the hole in the top of the body

10. Glue the nozzle to the center of the top of the body

11. Glue the solar panels to the sides of the body

For more information, write to AMSAT-NA, PO Box 27, Washington DC 20044



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Heard on the Downlink

by John Hansen, WAØPTV

The Index

You may recall that some months ago I put out a call for assistance in creating an index to the past few years of the AMSAT Journal. A number of individuals offered to help with this project. Claudio, I2NDT even sent me a copy of an index he had worked up for the early 1990s. Then I received a note from Gould Smith who already had completed an electronic index which was even keyworded. It was complete up through the middle of 1993. Buzz, WH6I, of the Journal editorial staff agreed to take this information and reformat it for publication. Then I added the material up through the end of 1993 and did some reformatting so it would fit on our printed pages. The result is contained in this issue of the Journal. The original Gould index actually has more information in it than you see in the published version. It included volume and issue numbers, keywording, and a listing regular features such as Apogee View and Heard on the Downlink with references to the topics contained in each column. It is formatted in such a way that it could be easily imported into virtually any standard database program. If you would like a copy of the electronic index, send a formatted disk and a return stamped mailer plus a small contribution to the P3D fund and I will send the index back to you by return mail.

Sampling KO-23

Ok, so you've heard a lot about these digital satellites and you've decided you would like to have a look and see what's on them. You've heard about world-wide messaging, digitized images, digitized voice files, and the software that is available on the birds. Perhaps you have decided you want to get into digital satellites yourself and you figure the people who know the most about them are the folks who are already active on the birds. But how to know who they are and how to contact them?

Perhaps you have a computer and a modem and maybe are also active on packet. Perhaps you saw the article I did for 73 Magazine last year describing the digital satellite node system whereby amateurs without satellite stations can work the digital birds simply by using their packet radio stations. But you've found that as yet, there aren't any satellite nodes in your immediate vicinity.

OK folks, a digital satellite node is now as close as your modem. Several months ago I installed a telephone port on my packet BBS. It is slow (2400 baud max), but as yet it is not heavily utilized. Most local folks still prefer to check in by radio. On a trial basis I'm going to open this port to AMSAT members. By checking in through the phone port you can get current directories of the files on KO-23 (and UO-22, for that matter), request that files be downloaded and sent to you, upload messages, and generally do virtually anything you would be able to do if you had your own digital satellite station. Here's how to use the system: Call 716-679-4767, 1200

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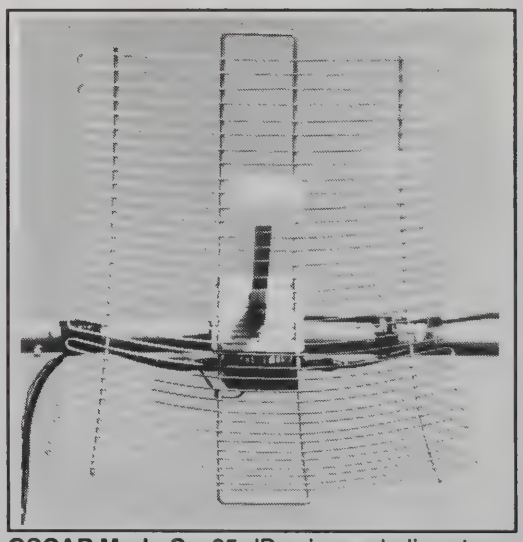

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or 2400 baud, 8-N-1. You will be prompted for your callsign. When you enter it you will probably be told that you are not a registered user and asked if you want to continue anyway. Type Y for yes. At this point you will be able to read messages from the BBS, but not write any of your own (except to me) until you have registered. To register, leave me a message with your AMSAT membership number and the password that you would like to use.

You will be able to read the satellite directory even on your first call. To do so type:

L> KO23DR (UO22DR for UO-22).

and you will get a listing of messages that contain KO23 directories. Two of these are generated each day. Read the latest of these messages and you will be seeing a directory of most of what is actually on the satellite. Some messages are excluded from the listing. For example, UO-22 is heavily used for packet mail forwarding and these messages are not of particular interest to non-gateway stations so they are excluded from the directory. Full information on decoding the directory listing can be obtained in the March, 1993, 73 Magazine article. It also contains information on requesting files from the satellite and uploading your own messages to the satellite as well as generally describing how the system works.

I will make every effort to get a file of instructions up and running on the BBS before this issue of the Journal is printed. You can obtain a copy by using the following command:

D SATINSTR

This should be adequate to get yourself up and running. If you want additional information, a BBS manual describing all of the functions of the BBS is available. Drop me a note on the BBS if you interested in a copy (yes, there is a small charge). Please note that this service is being provided on a trial basis. Ever since I wrote the software to link digital satellites to packet bulletin boards I have been under fire from a very small but very vocal minority who believe that the satellite might come to be dominated by individuals using the satellite nodes as their means of access. Despite the fact that a dozen of these nodes have set up operation world-wide over the past year, no one has produced any evidence that they have had more than an absolutely minimal impact on satellite loading. However, because there is concern over this issue, I will keep track of the quantity of phone port usage of the node to make certain that it doesn't negatively impact satellite usage by others.

The Nature of Volunteer Organizations

I have really mixed feelings about volunteer organizations. When I buy something from a commercial vendor and it doesn't work properly I expect to be able to call them on the phone and get it straightened out. In short, I expect service. After all I'm paying for the product and they are being paid for their efforts. But what do you do when a volunteer organization doesn't perform as expected? True, you are sending them money. But no one is getting paid to perform their volunteer functions. So how mad can you get at them? I've run into this dilemma with virtually every volunteer organization that I've ever been associated with, from the local radio club to the local Cable TV Advisory Board to AMSAT. The situation with respect AMSAT is more difficult than any other organization with which I am familiar. Because AMSAT tries to do so much more than most purely volunteer organizations, the potential for it to fall short of the mark in the eyes of its members and potential members is much greater.

Since I became Journal editor I seem to be noticing this more and more. When I listen to AO-13 I often hear folks grousing about some disagreement they've had with AMSAT over the years. I've felt that way myself on occasion. A couple of years ago I submitted an article to the AMSAT Journal for consideration for publication. I never heard back from them. Wow, I thought, how inconsiderate! Not even the decency to reply! Boy, what a difference a couple of years make. I am endeavoring mightily to keep up with my correspondence, but it is rather difficult. I really hope that no one finds themselves in the position of sending something in without a response.

But if you do find yourself in that circumstance, drop me a gentle reminder and I'll try to do better. So if I'm having trouble keeping up, imagine the problems faced by guys like Bill Tynan or Dick Jansson who are doing the real work of the organization. I hear Dick on AO-13 quite a bit.... and it certainly is wonderful that he has the time to enjoy the benefits of some of the projects that he has worked on in the past. But consider this: every hour that Dick (or Bill or Dick Daniels, or Stan Wood or the dozens of others) spends working on Phase 3D is an hour he is not playing with radios, not working the birds. From time to time folks who were extremely active in AMSAT simply disappear. I often wonder if they just didn't get enough time to play with the toys.

My point is this: AMSAT, along with every other volunteer organization, is inevitably going to disappoint its members occasionally. In volunteer organizations (even more than in commercial enterprises) things simply fall between the cracks from time to time. When I am dissappointed in this kind of organizaiton I have two choices: If I view myself as a consumer, my response is to become angry and complain about the quality of service. If I view myself as a part of the organization, I initially figure that these things just happen from time to time in volunteer organizations and then wonder if contributing more of my time, energy, and resources might result in fewer disappointments in the future.

AO-13 Scheduling

Those of you who have been active on AO-13 the last few months surely know that it has been, shall we say, "inconvenient" to operate. For one thing, it's been going through one of those periods where the prime operating times are in the middle of the night for most of North America. Secondly, it ran into a period of very long eclipses in December and the operating hours had to be curtailed more severely than during any time that I can remember. James Miller, G3RUH, one of AO-13's controllers, pointed out that these were the longest eclipses the satellite had ever experienced and, if the 1996 crash predictions are accurate, the longest it ever would experience.

If you find yourself wondering why this happened, take a look at James' article in this month's issue of the Journal. It is a paper that he presented at this year's Space Symposium which describes in detail exactly how AO-13's controllers determine its schedule.The good news is that by the time you read this things will already be improving both in terms of the operating hours and the satellite's attitude. So if you have been off the bird for a while, now's the time to hop back on.

Newsletters

I have nothing but respect for those trying to regularly put out amateur radio newsletters, whether they be general in nature or related to satellite operation. I did that gig locally for about five years and while it was a lot of fun, it was also a lot of work. So it was with some interest that a couple of issues of the PARC Amateur Radio Satellite Newsletter fell on my desk a couple of weeks ago. Bob Reisenweber, W3BBO and Larry Makoski, N2ELW are doing an excellent job of putting together a local satellite newsletter in the Piscataway, N.J. area. Published bimonthly, it covers a wide range of subjects, but seems to be most heavily

focused on newcomers. If you're living anywhere near Piscataway, you should be on their mailing list.

Help Wanted

We have asked for assistance with a number of projects in this Journal and the response has been really outstanding. There are, however, a few other areas in which you may be able to help AMSAT. First, the Journal really needs an advertising manager. This position would ideally be filled by someone who has some knowledge of the amateur radio marketing field, though quite frankly a willingness to write some letters and make some phone calls and a genuinely nice personality are far more important. This person's job would be to interface with our current advertisers and identify and follow up prospective new advertisers. Secondly, we could use someone to develop advertisements for AMSAT to be placed in this Journal and elsewhere. Graphic art design skills are essential for this position. If you are interested in either of these positions, contact me at one of the addresses below.

Secondly, here's a project that could make you famous. One of the types of packet radio bulletin boards that is most common world-wide was written by Jean Paul Roubelat, F6FBB. It is commonly referred to as the FBB BBS software. You may not have been aware of this, but general information, including uplink and downlink frequencies, for all amateur satellites as well as many others, is potentially available on all FBB BBS's and actually available on most of them. To access this information use the F command, followed by a T command and a C command. An L command will then give you a list of the satellites available. You type in the satellite number and you get the information about that bird.

There are just a couple of problems though. Complete files of information were distributed to BBS sysops about a large number of satellites several years ago. These files are simply straight text files with a filename of the form: XXXXX.SAT where XXXXX is the satellite catalog number. So, for example, the file 20442.SAT desribes LUSAT. Aside from being a couple of years out of date, the other "challenge" is that the files are written in French. This poses a problem for some BBS users who are not fluent in that language. I was thinking it sure would be nice to have the files updated and translated when I happened to stumble upon a copy of the Keith Baker's book "How to Use the Amateur Radio Satellites" (now in its 3rd edition) which has recently been distributed free to new members. This book contains a brief summary of each amateur satellite including uplink and downlink frequencies.

If someone were to edit this material into text files with the appropriate filenames (the catalog numbers are right in Keith's book), it would be a great public service. You could even become famous by putting a brief (please, brief!) credit line at the beginning of each file. If you are interested in doing this job, you need not contact me.... just write it and release it. Though please do send me a copy, I'd like to add it to my BBS.

Once again, please send any tips or other information to me at any of the following addresses:
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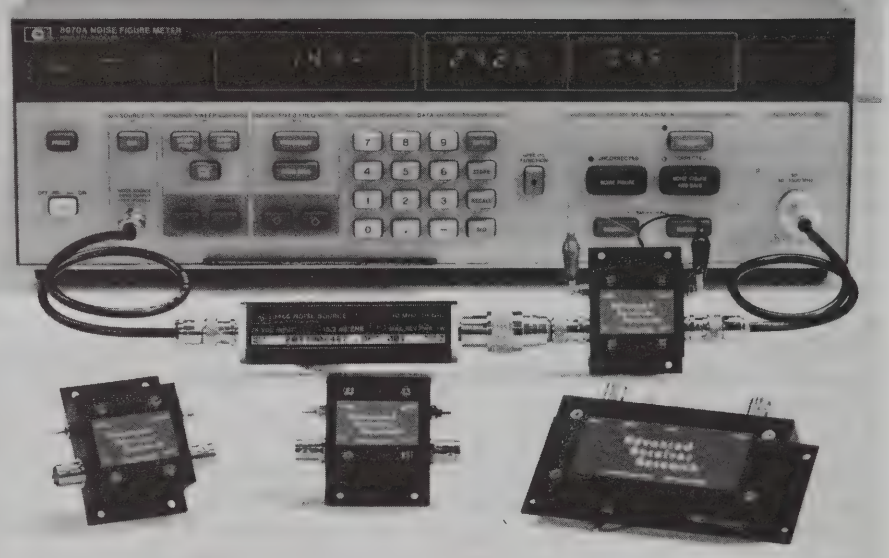

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P432VDA	420-450	<1.1	17	−20	Bipolar	$49.95
P432VDG	420-450	<0.5	16	+12	GaAsFET	$79.95
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SP50VD	50-54	<1.4	15	0	DGFET	$59.95
SP50VDG	50-54	<0.55	24	+12	GaAsFET	$109.95
SP144VD	144-148	<1.6	15	0	DGFET	$59.95
SP144VDA	144-148	<1.1	15	0	DGFET	$67.95
SP144VDG	144-148	<0.55	24	+12	GaAsFET	$109.95
SP220VD	220-225	<1.9	15	0	DGFET	$59.95
SP220VDA	220-225	<1.3	15	0	DGFET	$67.95
SP220VDG	220-225	<0.55	20	+12	GaAsFET	$109.95
SP432VD	420-450	<1.9	15	−20	Bipolar	$62.95
SP432VDA	420-450	<1.2	17	−20	Bipolar	$79.95
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Satellite Orbital Elements

by Ray Hoad, WA5QGD

Satellite	AO-10	UO-11	RS-10/11	AO-13	FO-20	AO-21	RS-12/13
Catalog No.	14129	14781	18129	19216	20480	21087	21089
Epoch Time	94024.05103246	94022.54990237	94024.51112470	94024.72776868	94022.02498298	94022.59338267	94023.25486395
Element Set	255	659	856	868	653	418	657
Inclination	27.1974	97.7943	82.9229	57.8659	99.0150	82.9419	82.9234
RA of Node	345.0665	44.0471	75.0490	271.7520	201.5769	250.4473	118.9396
Eccentricity	0.6022479	0.0012732	0.0013261	0.7209858	0.0540715	0.0036137	0.0029748
Arg of Perigee	148.8987	20.1247	65.1117	333.3841	310.7310	127.9378	149.4078
Mean Anomaly	267.9531	340.0459	295.1421	3.3067	44.8065	232.5054	210.8818
Mean Motion	2.05878528	14.69126429	13.72330004	2.09727795	12.83224067	13.74532122	13.74034012
Decay Rate	-.00000157	.00000220	.00000029	-.00000474	.00000032	.00000094	.00000069
Epoch Rev	7981	52892	33020	4300	18538	14958	14874
Satellite	**UO-14**	**AO-16**	**DO-17**	**WO-18**	**LO-19**	**UO-22**	**KO-23**
Catalog No.	20437	20439	20440	20441	20442	21575	22077
Epoch Time	94023.72027674	94023.71142341	94023.19000664	94023.72257873	94023.78031134	94022.73955110	94023.85609254
Element Set	958	759	758	759	758	459	354
Inclination	98.6014	98.6085	98.6093	98.6090	98.6095	98.4491	66.0869
RA of Node	110.4232	111.4985	111.2588	111.7965	112.0754	100.0846	222.1744
Eccentricity	0.0010738	0.0010626	0.0010786	0.0011363	0.0011686	0.0008316	0.0008987
Arg of Perigee	258.1040	257.4103	258.6026	257.4262	257.0604	9.2228	324.6351
Mean Anomaly	101.8939	102.5891	101.3939	102.5650	102.9274	350.9110	35.4071
Mean Motion	14.29818845	14.29874323	14.30012183	14.29988660	14.30082457	14.36884103	12.86283752
Decay Rate	.00000090	.00000036	.00000033	.00000022	.00000035	.00000077	-.00000037
Epoch Rev	20894	20895	20889	20897	20899	13219	6822
Satellite	**AO-27**	**IO-26**	**KO-25**	**MIR**	**POSAT**	**NOAA-10**	**NOAA-11**
Catalog No.	22825	22826	22830	16609	22829	16969	19531
Epoch Time	94024.20805866	94024.19945571	94023.12145410	94024.89373306	94024.17496986	94024.90557717	94024.88940835
Element Set	256	257	258	113	249	589	493
Inclination	98.6679	98.6696	98.5680	51.6149	98.6636	98.5115	99.1591
RA of Node	101.3787	101.3894	99.1055	185.5066	101.3681	38.2683	10.3872
Eccentricity	0.0008002	0.0008709	0.0010832	0.0004274	0.0009514	0.0014216	0.0011598
Arg of Perigee	272.5619	274.0164	241.2500	238.4510	260.3974	30.0469	172.3595
Mean Anomaly	87.4646	86.0022	118.7594	121.6066	99.6130	330.1524	187.7754
Mean Motion	14.27602782	14.27705052	14.28028626	15.59707808	14.27999725	14.24859195	14.12952794
Decay Rate	.00000024	.00000014	.00000032	.00003418	.00000112	.00000046	.00000109
Epoch Rev	1714	1714	1699	45369	1714	38220	27498

Notes from the field ...

Continued from page 1

various antenna designs. Dick Daniels, W4PUJ, AMSAT's North American P3D Team Director along with Dr. Tom Clark, W3IWI, P3D GPS experiment Team Leader, joined the group by telephone. Longtime AMSAT satellite builder Jan King, W3GEY, and Lyle Johnson, WA7GXD, from TAPR, were also present and served as technical advisors to both teams during the discussions.

Final designs for solar cells, solar panels, batteries, as well as the progress now being made on the spacecraft's overall structure were also discussed. In addition, possible integration sites in the Orlando/Cape Canaveral area were evaluated and several team members toured a candidate facility at the Orlando International Airport. A final selection regarding the most cost-effective location for Phase 3D integration will be made once firm rental price proposals are received and evaluated by the now AMSAT-NA/SFO combined Phase 3D integration team.

Dear Satellite Doctor:

I have absolutely no experience with amateur satellites. I enjoy operating HF and have no equipment for the bands above 10 meters except for a 2 meter HT. I have heard that I might be able to hear and perhaps even work, satellites launched by the former Soviet Union. I need some help getting started. I have an Icom 735 HF radio and a set of dipole antennas that I use on 80 through 10 meters. I do have access to an IBM compatible computer that could be used for tracking if I knew how to do it. Can you provide me with the following information:

1. Is it possible for me to begin listening for these satellites without acquiring any additional equipment? If so, how do I know when and where to listen?

2. What equipment will I need to acquire to become fully operational on these birds? I'm just getting my feet wet here and don't want to commit a lot of money at this point.

3. How far away will I be able to work other stations from my home QTH in Allentown, Pennsylvania?

4. Are there any operating skills that I will need to develop to use this new mode? Do I call CQ as I would to initiate other HF contacts?

5. Where can I go to obtain additional information?

Thanks,

Future Satellite Operator and AMSAT Member

Groundstation Diagnosis

by Mark Hoersten, N8VEA

If you think you might be interested in amateur satellite operation, perhaps the best way to start is by listening in on some of this exciting space activity. Receiving satellite downlinks is easy; your present station is all you need to get started. The low earth orbiting satellites from the former Soviet Union are common starting points because of their strong signals and easily accessible downlink frequencies.

There are three amateur satellites launched by the former Soviet Union that are very popular with beginners. RS-10/11 was launched June 23, 1987, RS-12/13 on February 5, 1991, and AO-21 (RS-14) on January 29, 1991. All three are in polar orbits with altitudes in the 1000 km range. The low earth orbit makes them accessible with a modest ground station and therefore attractive to newcomers. You have the equipment to begin receiving the downlink from each of these satellites.

The first step in chasing any amateur satellite is to predict when the satellite will be within sight of your ground station. You have access to a computer so next you need to get a satellite tracking program. AMSAT offers several programs that will run on IBM compatibles as well as a variety of other machines. One examples is INSTANTTRACK which has some of the most advanced features and outstanding graphics, but which does not support older CGA graphics monitors. Another excellent program is QUICKTRACK, which will display graphics on CGA and most hercules monochrome systems. In addition, ORBITS II is a CGA-based program that is (for a limited time) being given away free with new AMSAT memberships. Contact the AMSAT office for a complete description of the software offering.

Once you have a computer tracking program you will need to enter data that describes the orbit of the satellite of interest. This information is called Keplerian elements. A standard format for this information that you may see referred to is called the NASA 2-line format. The raw numbers are listed in two rows that can be directly read by some tracking programs.Many amateur radio related computer bulletin boards post the information in this format. Updated orbital elements for all of the amateur satellites are listed in each issue of the AMSAT Journal. Over time a satellite's orbital parameters change due to decay or, in some cases, rocket firings. Therefore, this information must be updated periodically for your tracking program. For RS-10/11, RS-12/13, and AO-21, the Keplerian elements should be good for several months.

It is important to enter this orbital information correctly otherwise you will be listening when the satellite is not within range and will never hear anything. Read the documentation that came with your tracking program carefully. Each program requires a slightly different format for entering the data. The Satellite Experimenter's Handbook published by the ARRL has a good discussion of satellite tracking and orbital elements and is useful to help understand what some of the numbers mean.

A second piece of information that is needed by the program is your location. The tracking program is going to perform a set of calculations that will tell you when the satellite will be above your horizon. In order to do this it needs to know where on the planet you are. For example Allentown Pennsylvania is located at 40 deg 35' N latitude, 75 deg 30' W longitude. You will also need to input your approximate elevation above sea level.

I would recommend starting with RS-10. RS-10/11 are two separate amateur tran-

sponder packages contained on the COSMOS 1861 navigational satellite. The RS-10 transponder is active in Mode A (2 meter uplink, 10 meter downlink), while the RS-11 transponder is used as a backup should the RS-10 develop problems. RS-10 should give you about four good passes per day. You will get two passes separated by the 105 minute orbital period and two more passes about 12 hours later.

Choose an upcoming pass of the satellite that will be at least 30 degrees above your horizon (elevation). Listen for the CW beacon on 29.357 MHz. You will have no problem hearing the beacon on your IC-735 transceiver without the use of a preamp. Once you are hearing the beacon at a solid signal level tune to the mode A transponder downlink. The transponders output is between 29.360 MHz and 29.400 MHz. The portion of the transponder below 29.380 MHz is used for CW contacts, and above is SSB. The RS-10 transponder is noninverting so stations will be using USB on the 2 meter uplink to generate a USB signal on the downlink. Tune across the downlink and you will find a number of QSOs in progress. A typical pass of the satellite only lasts 10 to 15 minutes so the contacts will usually be short exchanges of call signs, signal reports, and location (usually grid square). Operating procedures are very similar to what you find on HF, stations calling CQ trying to make a couple of contacts before RS-10 drops below the horizon. The time of the pass will determine the amount of activity on the satellite. A pass during the prime time evening hours will be packed with QSOs, while some late night or very early morning passes may have no one trying to use the satellite. So keep this in mind just in case you do not hear anything on the transponder downlink on your first try.

RS-12/13 are a set of transponders similar to RS-10/11 carried on the COSMOS 2123 satellite. The active mode is K which means an uplink on 15 meters and 10 meters downlink. Listen for the beacon on 29.408 or 29.454 MHz. The transponder output is 29.410 to 29.450 MHz.

AO-21 also has a strong downlink and will be easy to hear with your present station equipment. This satellite carries a digital signal processing module that is currently programmed to act as an FM cross-band repeater. The uplink is on 435.016 MHz and the down link is at 145.987 MHz. You can use a 2 meter HT to listen to the output of the repeater. Most FM transceivers only tune in 5kHz steps so you will not be able to tune the exact frequency. This is not a problem. Doppler shift due to the satellite's velocity as it approaches your location will cause the actual receive frequency to be shifted up. And as the satellite begins to move away, the apparent frequency will be lower than nominal. So for the first half of the pass listen on 145.990 MHz and then tune to 145.885 MHz during the second half.

While it may be possible to hear the downlink with just the rubber duck antenna, an outdoor antenna will provide more consistent results. Even an antenna in the attic will perform well. A 1/4 wave groundplane is easy to homebrew and works well for this satellite. Most HTs have plenty of receive sensitivity so you will not need to use a preamp to get a readable signal on the downlink. The first time I heard AO-21 on my HT (with an outdoor antenna) the signal was stronger than some of the local repeaters.

The orbit of AO-21 is similar to RS-10 so you will only get about 15 minutes of downlink on a pass. But unlike RS-10, the AO-21 FM repeater is not available full time for communications. The operating schedule is usually 6 or 7 minutes in the crossband repeater mode alternating with 3 or 4 minutes of telemetry. The actual operating pattern you hear may be different due to schedule changes. For example, past schedules have included voice announcements in English and many other languages.

If you are not able to hear any of these satellites double check the orbital elements entered into the tracking program. The numbers have many digits so its easy to make a mistake. Especially parameters such as decay rate which have many leading zeros. Also check for the correct time, the tracking program is probably set to UTC. If after double checking everything you have not had any luck, compare orbital predictions with someone else who is hearing the satellites to see if your prediction times agree. This will help you track down your problem.

Now that you can predict when a satellite is within range and can successfully hear the down link you may want to think about what is needed to conduct a 2-way satellite QSO. In general, you will need a technician (no-code or tech-plus) or higher license to operate on the satellites. Your uplink frequency needs to be in a band where you have operating privileges. The FCC views a satellite as a type of cross-band repeater, so it's legal to use the downlink in a band where you do not have privileges. For example, with mode A operation all you need is a no-code technician license to operate the 2 meter uplink even though the downlink is in the general license portion of the 10 meter band.

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Again, the best place to start is mode A on RS-10. You will need to add 2 meter SSB capability to your station for voice contacts on RS-10. Not much power is needed, 25W into a 1/4 wave ground plane will get you going. You will find that a 2 meter all-mode radio is more expensive than the FM only variety, but the extra investment is worth it if you plan to be active on satellites. Not only will a 2 meter sideband rig get you up and running on RS-10, but it can also be used as you upgrade to other satellites by becoming the downlink receiver for mode B on Oscar 13 or Oscar 10 (a 70cm radio will be required for the uplink). Many older 2 meter all-mode radios are now coming on to the market at reasonable prices as operators upgrade to newer and fancier equipment.

There have been some very good articles published on using RS-10 in the past year. The August 1993 issue of QST contains an excellent article by Walter Daniel, KE3HP. If you plan to work this satellite I would highly recommend reading his article.

Once you are operational on these satellites you will find that they easily cover the continental U.S., Canada, and the Caribbean. From your Allentown PA location, the kind of contacts you will be able to make depends on the pass of the satellite. For example if RS-10 passes directly over Bermuda the eastern part of the U.S will be covered as well. A pass that moves across the central part of the U.S. will let you make contacts as far as the west coast of North America.

For someone with no satellite experience, the best way to get started is to begin tracking some of the satellites and listening to the downlink. This will give you a chance to get your feet wet without adding additional hardware. Once you can hear the satellites, your interest will grow and you will begin planning for your first 2-way satellite QSO.

Additional Sources of Information

RS-10/11 & RS-12/13

The ARRL Satellite Anthology, 2nd Edition, (Newington: ARRL, 1992).

G. Smith, The RS Satellites Operating Guide (Washington: AMSAT, 1992).

S. Ford, "The EasySats," QST, September 1992, pp 30 - 34.

W. Daniel, "Getting Started with RS-10," QST, August 1993, pp 53 - 56.

AO-21

S. Ford, "You Have a Date with OSCAR 21," QST, November 1993, pp 70 - 71.

J. Sheets, "How To Work AO-21 From Your Mobil," The AMSAT Journal, May/June 1993, p 24.

P. Gowen, "OSCAR-21/RS-14 RUDAK on FM Transponder Mode," The AMSAT Journal, May/June 1993, pp 25 - 26.

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M. Davidoff, The Satellite Experimenter's Handbook, 2nd ed (Newington: ARRL, 1990), pp 6-1 through 6-18.

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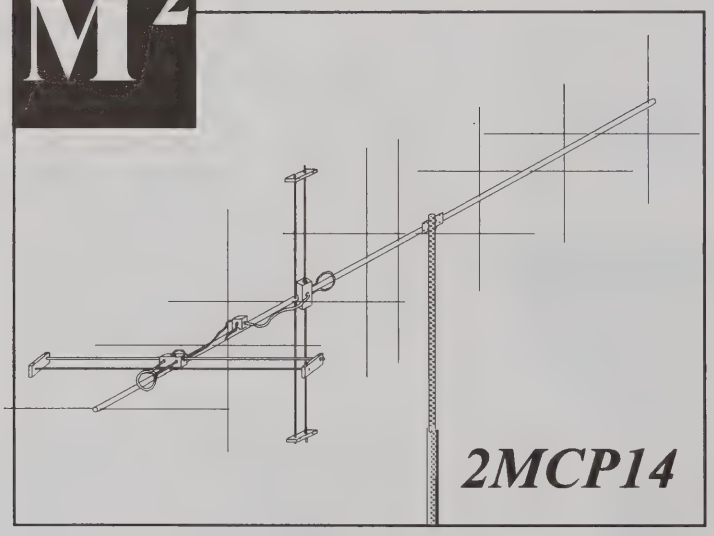

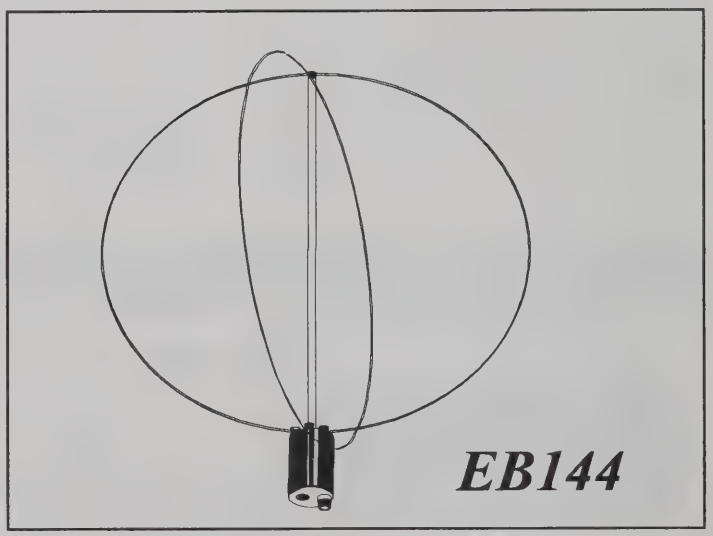

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See the Sept. QST review and find out just how well this versatile omnidirectional performer accesses high and low orbit satellites (inc.137 MHz weather). The compact EB144 is also surprisingly effective for mobile, nets, contests, and field day operations. Polarity is horizontal at the horizon, RHC overhead. For UHF, there's the companion EB432.

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Recovery of a Hole in the QuikTrak 4.0 STNMFILE file

by G. Gould Smith, WA4SXM

In QuikTrak 4.0 if you inadvertently name a satellite with a space or null string, that location is skipped when using the cursor keys to move through the satellite list. It appears that there is a "hole" in the list that cannot be accessed. The procedure described in this note will enable you to get the location back. Of course you can always reload the file STNMFILE from the distribution disk but if you have invested time in ordering the satellites or entering mode strings and beacon frequencies reloading may not be an attractive option.

To avoid this problem in the future be sure to use a letter, number or punctuation character for the name field (first entry) of each satellite position. Don't use the delete key to remove an old name and then hit <CR> for the name. This is the usual cause of the problem. N4HY, the author of QuikTrak 4.0, suggests using a period as a "place holder" in the file. Before beginning the procedure you should make a copy of your STNMFILE file on a floppy or in another directory on your hard disk. This is in case you make an error you can at least get your old file back and not be worse off than before you started.

Figure 1 shows a portion of an STNMFILE file from QuikTrak as displayed in a hex editor program. This file has an error in it of the type we want to correct. Next you should run QuikTrak and note the name of the "good" satellites both before and after the "hole". In the example they were RS-10/11 and AO-21.

Use a hex editor to display the file as in the figure. Your editor may differ but most editors with hex capability display the hex bytes of the file in the main part or left side of the display. On the right is the ASCII interpretation of the hex data.

Now note that every satellite file ends with hA (ASCII) or 68,41 (HEX). We have underscored each occurrence of this byte pair in the file. The last two bytes of the first line, for example, are 68,41 and the next satellite is RS-10/11. Now follow down the file 36 bytes. You will find another hA (68,41). This is the end of the RS-10/11 entry. If the next satellite were valid the first character after the A (41 hex) would be some letter, number or punctuation character. In this example it is not. If you look on the hex side you will see that it is a 00 or space. This is what must be corrected to recover the "slot" in the file. I replaced the 00 with 54 (ASCII T). This had the effect of naming the next satellite TTS-35. Be sure you know how to use your editor since you are directly modifying a disk file. Be sure your editor does not shift things to the right as you type. You want to overwrite the location not insert new data.

After making the change in the example file I started QuikTrak and opened its DATA EDITOR. In the location that had been blank there was now a satellite named TTS-35 as expected. I then renamed it in QuikTrak 4.0 to one of the satellites I normally use and wanted to have at that position. If you already have the desired satellite in another position, move the cursor and bring up the satellite. Now carefully delete the name leaving just a period in the first position. DO NOT PRESS RETURN. Instead press Insert to accept the changes you have made.

If you do not want any "holes" or periods in the middle of the file a suggestion is to move the last satellite in your old file to the hole you are trying to fill. Now use QK to reload the data from your latest 2-line data file and all should be as you desire.

This is the problem byte.

```
File: C:\TEMP\STNMFILE                                          HEX   (masked )
000110  31 20 45 6C 2E 53 65 74  20 33 37 39 00 00 68 41  1 El.Set 379..hA
000120  52 53 2D 31 30 2F 31 31  00 C3 51 8B 45 FE A8 01  RS-10/11..Q.E...
000130  31 38 31 32 39 20 45 6C  2E 53 65 74 20 34 34 32  18129 El.Set 442
000140  00 00 68 41 52 53 2D 31  32 2F 31 33 00 C3 51 8B  ..hARS-12/13..Q.
000150  45 FE A8 01 32 31 30 38  39 20 45 6C 2E 53 65 74  E...21089 El.Set
000160  20 33 37 39 00 00 68 41  00 54 53 2D 33 35 00 61   379..hA.TS-35.a
000170  78 00 51 8B 45 FE A8 01  4A 53 43 2D 33 20 45 6C  x.Q.E...JSC-3 El
000180  2E 53 65 74 20 31 31 00  00 00 68 41 41 4F 2D 32  .Set 11...hAAO-2
000190  31 00 30 36 00 C3 51 8B  45 FE A8 01 32 31 30 38  1.06..Q.E...2108
0001A0  37 20 45 6C 2E 53 65 74  20 35 39 35 00 00 68 41  7 El.Set 595..hA
0001B0  4D 49 52 00 20 34 00 00  99 C3 51 8B 45 FE A8 01  MIR. 4....Q.E...
0001C0  31 36 36 30 39 20 45 6C  2E 53 65 74 20 36 35 37  16609 El.Set 657
0001D0  00 00 68 41 53 41 52 41  00 35 00 30 00 C3 51 8B  ..hASARA.5.0..Q.
0001E0  45 FE A8 01 32 31 35 37  38 20 45 6C 2E 53 65 74  E...21578 El.Set
0001F0  20 33 37 38 00 00 68 41  4B 4F 2D 32 33 00 31 00   378..hAKO-23.1.
000200  99 C3 51 8B 45 FE A8 01  32 32 30 37 39 20 45 6C  ..Q.E...22079 El
000210  2E 53 65 74 20 20 38 30  00 00 68 41 2E 00 74 65  .Set  80..hA..te
000220  6F 72 20 32 2D 30 38 00  45 FE A8 01 31 33 31 31  or 2-08.E...1311
000230  33 20 45 6C 2E 53 65 74  20 36 35 30 00 00 68 41  3 El.Set 650..hA
```

Figure 1: A QuikTrak 4.0 STNMFILE as viewed by a hex editor

AMSAT-NA MEMBERSHIP FORM

Name: _____

Call: _____

Address: _____

_____

State/Prov: _____

Zip/PC: _____

VISA/MC #: _____

Exp. Date: _____

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Compiled by G.Gould Smith, WA4SXM, Edited for Journal Publication by Buzz Gorski, WH6I

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PHASE 3D

The AMSAT Phase 3D Spacecraft	Jansson, Dick, WD4FAB	Sep/Oct 93
Mode "B" Will Fly on Phase 3D	editor	Jul/Aug 93
Phase 3D Spacecraft Construction Activities	Jansson, Dick, WD4FAB	Jul/Aug 93
Apogee View	Tynan, Bill, W3XO	May/Jun 93
The New Shape of P3-D	Meizner, Karl, DJ4ZC	May/Jun 93
Phase 3D Project Planning Meeting	various	May/Jun 93
Revised Phase 3D Design Finalized	Jansson,WD4FAB; Daniels W4PUJ; Tynan, W3XO	Mar/Apr 93
AMSAT Phase 3D Antenna Design Review, Phase 3D HF/UHF/MicrowaveAntennas	Wood, Stan, WA4NFY and Jannson, Dick, WD4FAB	Mar/Apr 93
New Agreement with the European Space Agency on Phase 3D Design	Jansson, Dick, WD4FAB	Jan/Feb 93
Apogee View	Tynan, Bill, W3XO	Jan/Feb 93
A New Challenge for the Phase 3D Project	Daniels, Dick, W4PUJ	Nov/Dec 92
Phase 3D Still Needs Your Help	Tynan, Bill, W3XO	Sep/Oct 92
AMSAT P3D Satellite Project at Weber State University	Harward, Kelly, Crookston, Mark & Butler,Ralph	Jul/Aug 92
Phase 3D Progress Report	Daniels, Dick, W4PUJ	May/Jun 92
AMSAT Phase 3D Project Update	Daniels, Dick, W4PUJ	Mar/Apr 92
Phase III-D has a Go for Launch	Deskur, Drew, KA1M	Sep 91
The Second Experimenter's Meeting for Phase 3-D, part II	Guelzow, Peter, DB2OS, trans by Don Moe,DJ0HC/KE6MN	Sep 91
An Educational Broadcast Transponder for Phase 3D	Van DeGroenendall, Hans, ZS6AKV	Sep 91
The Second Experimenter's Meeting for Phase 3-D, part I	Guelzow, Peter, DB2OS, trans by Don Moe,DJ0HC/KE6MN	July 91
Initial Phase-3D Experimenters Meeting Sponsored by AMSAT-DL	Guelzow, Peter, DB2OS, trans by Don Moe,DJ0HC/KE6MN	Nov 90
Commentary on the Phase III-D Kick Off Meeting Minutes	McGwier, Bob, N4HY	Nov 90

SATELLITE OPERATION

An Amateur Satellite Operation Upgrade Path	Smith, G. Gould, WA4SXM	Sep/Oct 93
SAREX QSL Information	Bauer, Frank, KA3HDO	May/Jun 93
How To Work AO-21 From Your Mobile	Sheets, John, N8QGC	May/Jun 93
OSCAR-21/RS-14 RUDAK on FM Transponder Mode	Gowen, Pat, G3IOR	May/Jun 93
You, too, can contact space! QRP to the satellites	Bass,Michael, N7WLC/5	May/Jun 93
Heard on the Downlink	Hansen, John, WA0PTV	May/Jun 93
Spotlight On: KITSAT-OSCAR-21	Magliacane, John, KD2BD	Mar/Apr 93
Heard on the Downlink	Hansen, John, WA0PTV	Mar/Apr 93
Another Banner Year Planned for SAREX	Bauer, Frank, KA3HDO	Jan/Feb 93
Sarex Frequencies on 1993 Space Shuttle Missions	BauerFrank, KA3HDO	Jan/Feb 93
Computer Processing of UO-22 and KO-23 Images	Daniel, Walter,N3KVQ	Jan/Feb 93
Gateways to the 21st Century	Kasser, Joe, W3/G3ZCZ	Jan/Feb 93
Hungry for additional satellite info?	Smith, Gould, WA4SXM	Jan/Feb 93
Spotlight On:Fuji-2/OSCAR 20	Magliacane, John, KD2BD	Nov/Dec 92
Keplerian Element Checksum Prog.	Campbell, Dick, N3FKV	Nov/Dec 92
SAREX Hardware Configurations and Flight Operations Support	Bauer, Frank,KA3HDO & McFadin, Lou,W5DID	Sep/Oct 92
Three SAREX Flights Planned for 93		Sep/Oct 92
Use of ... Satellite Signals to Inspire Interest in ...Developing Countries	Van de Groenendaal, L.J. Hans, ZS6AKV	Sep/Oct 92
Mode S - Tomorrow's Downlink?	Miller, James, G3RUH	Sep/Oct 92
Spotlight On: The Microsats	Magliacane, John, KD2BD	Sep/Oct 92
OSCAR 0: An Introto EME for the Satellite Operator (part 2)	Soifer, Ray, W2RS	Sep/Oct 92
AMSAT QSL Bureau	Yantis, Perry, WB8OTH	Sep/Oct 92
Spotlight On: RS10/RS11 and RS12/RS13	Magliacane, John, KD2BD	Jul/Aug 92
Back to Basics: Using the OSCAR-Locator	Berglund, Keith,WD5ZDP	Jul/Aug 92
OSCAR-13 Operations Report	Miller, James, G3RUH	Jul/Aug 92
Spotlight On: UoSat-OSCAR-22	Magliacane, John, KD2BD	May/Jun 92
SAREX Payloads Abound on 1992 Missions	Bauer, Frank H., KA3HDO	Mar/Apr 92
Welcome to the Z9 Club	MacAllister, Andy,WA5ZIB	Mar/Apr 92
Spotlight On: AMSAT-OSCAR-13	Magliacane, John, KD2BD	Mar/Apr 92
Improvements for the Kansas City Tracker/Tuner	Barger, Joe, N6KK	Mar/Apr 92
N4HY Quiktrak v4.0a Review	Pugh, Keith, W5IU	Mar/Apr 92
Decoding RS-12/13 Telemetry	Bergland, Keith, WB5ZDP	Jan/Feb 92
Spotlight On: UoSat-OSCAR-11	Magliacane, KD2BD	Jan/Feb 92
Micro Gateways Abound	Medley, David, KI6QE	Jan/Feb 92
The UO-22 Earth Imaging System	Ward, Jeff, G0/K8KA	Nov/Dec 91
The Poor Man's Satellite	MacAllister, Andy,WA5ZIB	Sep 91
Update on DSES 60' Dish Project	White, Jim, WD0E	Sep 91
AMSAT Tech Tips	Berglund, Keith, WB5ZDP	Sep 91
STS37 Review: First Flying Hamfest	Tynan, Bill, W3XO	July 91
Microsat Packet Gateway Operations	Lawson, John, NL7NC	May 91
Poor Boy Satellite Station	Fox, Allen J. IV, N5LKJ	May 91
Marine Mobile QSOs Via OSCAR 13 (Mode Sea)	Burden, William,WB1BRE	Mar 91
The Term "Hams in Space" Takes On a New Meaning	Tynan, Bill, W3XO	Mar 91
Shuttle Amateur Radio Experiment (SAREX)	Parise, Ron, WA4SIR	Mar 91

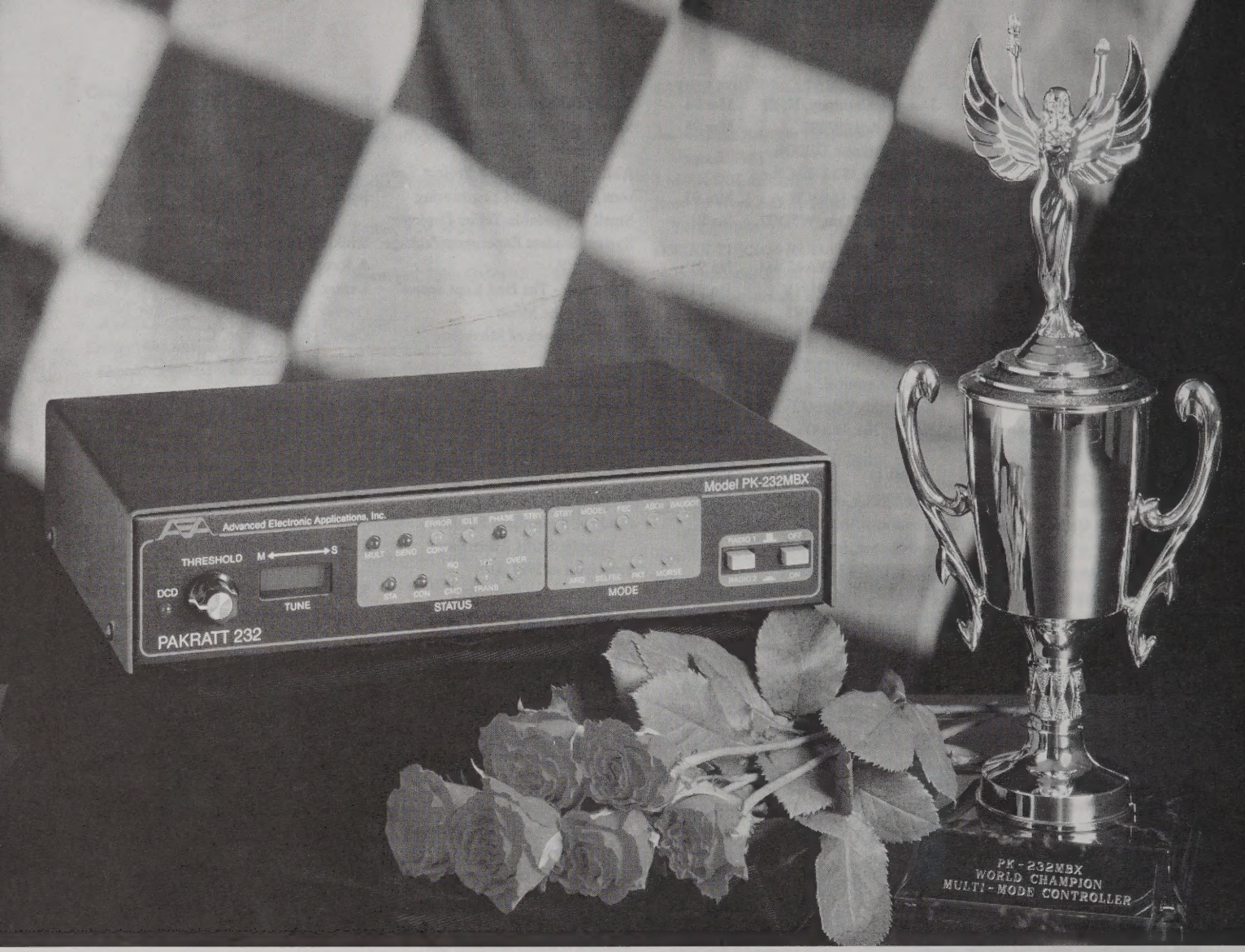
AMSAT-NA Operations Report	Duncan, Courtney, N5BF	Mar 91
Software Fix	Welch, Roy, W0SL	Mar 91
RADIO-M1/RUDAK-2	Peter Guelzow,DB2OS, Joe Kasser,W3/G3ZCZ, Leo Labutin,UA3CR	Mar 91
SAREX Hardware Development	McFadden, Lou, W5DID	Jan 91
Decoding Telemetry from the Amateur Satellites	Smith, Gould, WA4SXM	Jan 91
Mode S: Plug and Play!	Krome, Ed, KA9LNV	Jan 91
Project BADR-1 Decay	Ensign, Rich, N8IWJ	Jan 91
Chaminade Students Receive Telemetry from DOVE	Strieby, Ann	Jan 91
Satellites in the Classroom	Allen, Kermit R.	Nov 90
Higher Orbits	Kondratko,Valery,UV3DQE	Nov 90
Telemetry: Our Greatest Asset	Kasser, Joe, W3/G3ZCZ	Sep 90
The Telemetry Formats of JAS-1b/Fuji-OSCAR 20	JR1NVU	Sep 90
ZRO Test Update	MacAllister, Andy,WA5ZIB	Jul 90
CQ Earth, MIR Calling	Kondratko,Valery,UV3DQE and Kasser, Joe, G3ZCZ	May 90
Two Ham-in-Space Shuttle Missions Coming Up	Clark,W3IWI, Parise, WA4SIR, Tynan,W3XO	Mar 90
PACSAT Expections and Prep.	Branegan, John, GM4IHJ	Mar 90
Hints On Using the OSCAR-13 Mode S Transponder	McCaa, William, K0RZ	Mar 90
DX'ing the OSCAR's	Fail, John KL7GRF/W6	Mar 90
Weather Satellite Imagery	Wallach, Jeff, N5ITU	Nov 89
Mobile and Portable Ground Stations	Hall, Tom, N6DGK	Aug 89
Getting On Frequency While Using OSCAR-13	McMahan, M.W.,K4GMJ	Aug 89
Getting Started with Amateur Radio Satellites	Dzekevich, Joe,K1YOW	Aug 89
New UoSAT-OSCAR-11 Gateway Station On-line	Forbes, Ross, WB6GFJ	Aug 89
A Beginner's guide to Packet BBS Operation	Kasser, Joe, G3ZCZ	Aug 89
The Terminology Used in Orbital Predictions	Kasser, Joe,G3ZCZ	Aug 89
DOVE: A MicroSat Classroom Worldwide Messenger	Ensign, Richard, N8IWJ	Aug 89

SATELLITE THEORY

AMSAT-OSCAR 13 Eclipses	Ratcliff, Graham, VK5AGR	Nov/Dec 93
May the Force Be With You	Miller, James, G3RUH	Jan/Feb 93
Measure AO-13 Squint Directly	Miller, James, G3RUH	Jan/Feb 93
Microsat Engineering Test Results, August 1992	White, Jim, Rahn, Bruce & Williamson,Paul	Nov/Dec 92
DOVE Spin Rate Experiment	Feloney, Huybers, Meskell & Seidman	Jul/Aug 92
The Evolution of Amateur Satellite Telemetry	Smith, Gould,WA4SXM	Jul/Aug 92
OSCAR-13 Operations Report	Miller, James, G3RUH	Jul/Aug 92
Orbit Selection Considerations for Fourth Generation AMSAT Spacecraft	King, Jan, W3GEY	May/Jun 92
The Shape of Bits to Come	Miller, James, G3RUH	July 91
The Orbital Decay of AMSAT-OSCAR 13?	Meinzer, Karl, DJ4ZC	Jul 90
A Proposed Standard for Packetized Telemetry	Kasser, Joe, W3/G3ZCZ	Jul 90
An Alternate Approach for "Precise" Doppler Shift Determination	McMahan, Maury, K4GMJ	Jul 90
Satellite Orbital Elements	Rosenberg, Eric, WA6YBT	Mar 90
MicroSat Hitchhiker, An Alternative to Phase IV	Reynolds, A., WD9IYT	Nov 89
AMSAT-NA Phase IV Project, Lessons in Distributed Engineering	Jansson, Dick, WD4FAB	Nov 89
Small Expendable-Tether Deployer System Student ExperimentPackage SEDS SEP	Stluka, Edward,W4QUA, & Rupp, Charles,W4HIY	Nov 89
Telemetry - The Best Kept Secret	Kasser, Joe, G3ZCZ	Aug 89
Sailing to the Moon	Garvey, John, N6VHP	Aug 89
The First Flock of MicroSats	Clark, Tom; Duncan, C.; King, J.; & McGwier, B	Aug 89
The Terminology Used in Orbital Predictions	Kasser, Joe, G3ZCZ	Aug 89

MISC. TECHNICAL

AMSAT-OSCAR 13 Eclipses	Ratcliff, Graham, VK5AGR	Nov/Dec 93
Study of RadioSport Satellite Doppler Shifrt Anomalies	Branegan, J. GM3IHJ	Nov/Dec 93
Principles of HELAPS Transponder Amplifiers	King, Jan, W3GEY	Sept/Oct 93
Spacecraft Engineering Bibliography	Daniel, Walter KE3HP	Sept/Oct 93
Using RS-12 Mode "K" Anomalous Propagation	Gowen, Pat, G3IOR	Jul/Aug 93
Small iS beSteSt	Miller, James, G3RUH	Jul/Aug 93
A Case for the 5.8 GHz Band	Wilson, Graeme, VK4FXL	Jul/Aug 93
Monitoring AO-13 Battery Usage	Ratcliff, Graham, VK5AGR	Jul/Aug 93
Ground Station Tracking Via Packet	Bruninga, Bob, WB4APR	May/Jun 93
A Satellite Mode S Loop Yagi Antenna	Krome, Ed, KA9LNV	May/Jun 93
A 60cm S-Band Dish Antenna	Miller, James, G3RUH	Mar/Apr 93
Tracking the Army/Navy Football Game Via Packet	Brunings, Bob, WB4APR	Mar/Apr 93
Gateways to the 21st Century	Kasser, Joe, W3/G3ZCZ	Jan/Feb 93
Receiving Arsene on S Band	Krome, Ed, KA9LNV	Jan/Feb 93
Satellite S Band: Become QRV on Our Highest Band	Krome, Ed, KA9LNV	Nov/Dec 92
DSP and the Average Satellite Operator	Smith, Gould, WA4SXM	Nov/Dec 92
Mode S - Tomorrow's Downlink?	Miller, James, G3RUH	Sep/Oct 92
OSCAR 0: An Intro to EME for the Sat Operator (part two)	Soifer, Ray, W2RS	Sep/Oct 92
Is the Satellite Where You Think It Is?	Smith, Gould, WA4SXM	May/Jun 92
A Mode J Receiver Filter Kit	Jansson, Dick, WD4FAB	May/Jun 92
An Alternative Approach to 9600 Baud Reception	Krome, Ed, KA9LNV	Mar/Apr 92
Microsats for ALL! Project EchoSat	Converso, Pedro, LU7ABF	Mar/Apr 92
A Report on the Design Principles of the Ariane 5 Launcher	Long, Ron, W8GUS and Jansson, Dick,WD4FAB	Nov/Dec 91
Editor's Historical Note	Long, Ron, W8GUS	Nov/Dec 91
OSCAR Zero: An Introduction to EME For The Satellite Operator	Soifer, Ray, W2RS	Nov/Dec91
Microsat Motion and Stabilization (and why we care about it)	White, Jim, WD0E	Sep 90
Modifications to the G3RUH 400 Baud TM Demodulator	Krome, Ed, KA9LNV	Jul 90
An Alternate Approach for "Precise" Doppler Shift Determination	McMahan, Maury, K4GMJ	Jul 90
Using the G3RUH 1200 PSKModem with the AEA PK-232	Forbes, Ross, WB6GFJ	May 90



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